

## AN ABSTRACT OF THE THESIS OF

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Title: Medical Waste Treatment Techniques Used by Hospitals in Oregon, Washington, and Idaho.

### Redacted for Privacy

Abstract approved: \_\_\_\_\_

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Medical waste is heterogeneous in that it consists of infectious, radioactive, chemical, chemotherapy, and regular solid waste. If not handled properly, medical waste poses risks to both humans and the environment. Large volumes of medical waste are generated every year. Therefore, medical waste management is a significant concern for hospitals. The two main purposes of this study were: (1) to investigate medical waste practices in hospitals in Oregon (OR), Washington (WA), and Idaho (ID) (EPA Region X); and (2) to gather and compare information about medical waste treatment techniques used by hospitals in these three states. This study was conducted from September to November, 1993. Questionnaires were sent to 225 hospitals in OR, WA, and ID. 72.5 percent of hospitals in these three states returned questionnaires.

The results showed that the majority of hospitals generated more than 400 pounds of medical waste per week and more than 150 pounds of infectious waste per week. Ninety percent of hospitals adopted infectious waste definitions from more than one organization, such as the Occupational Safety and Health Administration (OSHA), Joint Commission on the Accreditation of Healthcare Organization (JCAHO), American Medical Association (AMA), or American Practitioner of Infection Control (APIC), in

addition to state regulations. The six most frequently reported categories of infectious waste were blood specimens and blood products (96.9%), all sharps (93.7%), microbiology laboratory waste (89.9%), pathological waste (89.9%), body parts (80.4%), and waste from surgery rooms (77.2%).

Most hospitals in this region had Advisory Committees overseeing waste management, which included the treatment and disposal of infectious waste. However, only 55.3 percent of hospitals reported segregating infectious waste from other medical waste, which means that hospitals may be over-managing their medical waste. The results also showed that hospitals generally labeled infectious waste (91.9%), radioactive waste (88.7%), chemical waste (76.3%), and chemotherapy waste (62.1%). An average of 81.4 percent of the hospitals had special areas for waste storage. For example, radioactive waste was usually stored on-site, whereas infectious waste was usually retained off-site.

Only ninety-six hospitals (59.6%) in the three states reported disposing of sharps differently from other waste. Incineration (33.9%) and transportation to an off-site treatment facility (33.9%) were the two most commonly reported techniques for sharps treatment and disposal. Hospitals in OR and WA generated more chemotherapy waste (85.4%) than those in ID (14.6%), and OR and WA hospitals either incinerated (43.2%) and/or disposed of this waste as hazardous waste (44.1%).

Most hospitals in this region reported that they no longer operated their incinerators (45.6%). However, the distributions for incinerator use were not homogeneous by state ( $\chi^2_{df=4} = 20.8$ ;  $p < 0.005$ ). The major factors contributing to these differences were larger than expected numbers of incinerators which: (1) had never been operating (OR); (2) were no longer in use (WA); and (3) were currently in use (ID). Hospitals that still operated their incinerators reported that they disposed of incineration ash in state sanitary landfills. More stringent state requirements regarding air pollution control had forced the closure of hospital incinerators in OR and WA.

The most frequently used medical waste treatment technique reported by hospitals was the hiring of private medical waste haulers to treat waste off-site (61.5%). Frequently used on-site waste treatment techniques included autoclaving (32.3%) and pouring waste into the municipal sewage system (46.6%). In addition to these practices, hospitals deposited waste off-site in landfills and adopted two new technologies as off-site medical waste treatment techniques: microwaving (5.6%) and Electro-Thermal-Deactivation™ (ETD™) (13.7%).

Several recommendations were made based on the results of this study: 1) Federal and state agencies should draft universal definitions of medical and infectious waste to eliminate confusion about what kinds of waste should be regulated; 2) Hospitals should monitor their medical waste segregation practices, especially segregation of infectious waste in order to help hospitals reduce their waste management costs; 3) More studies regarding radioactive and chemotherapy waste handling and disposal techniques in hospitals are strongly recommended because of the particular risks that they pose; 4) The environmental impact and efficiency of new techniques such as ETD™ should be assessed; and 5) A similar study might be conducted in other types of healthcare facilities, such as long term care facilities, dentist and physician offices, which also produce large volumes of medical and infectious waste.

Medical Waste Treatment Techniques Used by Hospitals in  
Oregon, Washington, and Idaho

By  
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A THESIS  
submitted to  
Oregon State University

in partial fulfillment of  
the requirements for the  
degree of  
Master of Science

Completed March 1, 1994.

Commencement June 1994.

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Typed by Pornwipa Klangsin

## ACKNOWLEDGMENTS

Many people have helped me throughout the process of this study. It is my pleasure to take this opportunity to give my thanks and acknowledgment for their contributions.

First, I would like to give great thanks to my parents, Mr. Thavil and Mrs. Jarassri Klangsin who gave me the incomparable opportunity to study in the US. I treasure their encouragement and support always. Also, I would like to thank the Royal Thai Government for their partial financial support of this study.

I would like to give my thanks to Dr. Anna K. Harding for her valuable encouragement, guidance, input, support, and for providing me the opportunity to earn my graduate degree at Oregon State University. I also would like to thank Dr. Leonard Friedman, Dr. Susan Prows, and Dr. Lavern Weber for their guidance.

Ms. Pam Bodenroeder provided me assistance in developing and preparing the questionnaires for this study.

I extend my heartfelt thanks to Ms. Nadia Aziz for her editorial assistance, encouragement and emotional support during my two-year stay at Oregon State University.

Last, but by no means least, I would like to express my deepest gratitude to Ms. Jane Jorgensen for her assistance with statistical analysis and time in making this thesis readable.

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# **Medical Waste Treatment Techniques Used by Hospitals in Oregon, Washington, and Idaho**

## **Chapter I INTRODUCTION**

### **Background**

During the 1980s, several incidents involving the disposal of medical waste caused significant public concern in many areas of the United States. For example, in Westchester, New York, the owners of an abandoned warehouse were indicted for illegally storing 1,400 red bags of medical waste (Council on Scientific Affairs, 1989). In 1987, twelve Indianapolis children were found playing with vials of blood at a dumpster outside a physician's office (Gellerman, 1988). Two of these children later tested HIV positive. In the same year, hospital waste from a Manchester, NH, landfill was dislodged and spread over neighboring land as a result of heavy rains (Gellerman, 1988). More recently, in 1988, two bags of medical waste containing syringes, IV tubing, and prescription bottles, washed up on the beaches of several east coast states, leading to the temporary closure of a dozen beaches (Baker, 1988; Bussey et al, 1988; Morgenthau, 1988; Herhkowitz, 1988).

The public has associated these incidents with AIDS and Hepatitis B virus (HBV) epidemics, and responded with fear. This widespread outcry effectively forced Congress to take action regarding the disposal of medical waste. The Medical Waste Tracking Act (MWTa) was enacted in 1989 as a two-year demonstration program to document the amount of medical waste produced and to monitor disposal strategies. Connecticut, New York, New Jersey, Rhode Island and the Commonwealth of Puerto Rico participated in

this demonstration program ( US. EPA et al, 1991). The demonstration program resulted in the establishment of regulations that apply to facilities that generate, transport, treat, destroy, and dispose of medical waste (TSDD facilities) (40 CFR Part 259). These regulations are enforced by the US. Environmental Protection Agency (US. EPA, 1990).

Several other federal agencies also regulate medical waste management (Reinhardt & Gordon, 1990). The Centers for Disease Control (CDC), the Occupational Safety and Health Administration (OSHA), and the Nuclear Regulatory Commission (NRC) have passed regulations regarding medical waste disposal practices and safety issues (CDC, 1987; FR, 1991; FR, 1981). In addition, 43 states including Oregon, Washington, and Idaho have passed state-specific laws regarding the management of medical waste (Lumsdon, 1992). Additionally, hospitals are governed by standards set forth by the Joint Commission on the Accreditation of Healthcare Organization (JCAHO), and the American Hospital Association (AHA), in order to be accredited (AHA, 1990; JCAHO, 1992).

Medical waste is defined in 40 CFR 259.10 as "any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in related research, biological production, or testing" (US. EPA, 1990). Tickell and Watson (1992) define medical waste as "the name given to rubbish containing human and animal tissue, blood, excreta, drugs, swabs and syringes as well as any non-toxic items". Medical waste is, therefore, somewhat similar to municipal solid waste in that it is very heterogeneous (Cross, 1990). Medical waste, however, is not synonymous with infectious waste.

The EPA and CDC differ in their definitions of infectious waste (Clark, 1989). The EPA defines infectious waste as "waste capable of producing an infectious disease." This definition assumes that the conditions necessary for infection to occur, which include a virulent pathogen, sufficiently high dose, portal of entry, and host resistance, are present. CDC describe infectious waste as "waste with the potential for causing infectious disease during handling and disposal and for which some special precautions appear prudent.

Hospital waste for which special precautions appear prudent include microbiology laboratory waste, pathology waste and blood specimens or blood products" (Clark, 1989).

Because infectious waste is not uniformly defined by the CDC and EPA, each agency has categorized this waste differently (Reinhardt & Gordon, 1991). The CDC have categorized infectious waste as microbiology laboratory waste, pathological waste, blood specimens and blood products, sharps and isolation waste. The EPA's categories are more extensive, including isolation waste, cultures and stocks, sharps, contaminated animal carcasses, and body parts and bedding. Although the categories appear to be different, the types of waste identified by the two agencies are actually quite similar in nature.

The great discrepancies between regulations, guidelines and standards that apply to medical waste, and particularly to infectious waste, have caused confusion among the hospital industry regarding proper management procedures. This confusion may be caused by several factors. First, the definition of infectious waste is defined differently by individual states, and even by hospitals in the same state. The confusion over the definition affects the classification of medical waste produced in hospitals. Second, medical waste in each state may be regulated differently: medical waste in some states is regulated as solid waste, hazardous waste, and medical waste undergoing approved methods before disposal. In some states guidelines are only now being proposed.

Federal regulations have also limited alternatives to on-site treatment methods of medical waste. As a consequence of the enforcement of the Clean Air Act of 1990, on-site hospital incinerators have been required to be renovated, replaced, or even closed down (Cruz, 1992). Therefore, waste that was incinerated must now receive alternate treatment. Regulations have also forced hospitals to change medical waste management practices. For example, all infectious waste has to be treated before being buried in the landfill, or has to be segregated and labeled before it is allowed to be hauled to commercial facilities.

## **Statement of the Problem**

During the past five years, various aspects of medical and infectious waste management have been researched. Studies have included a survey of infection waste practices in Washington (Washington Department of Ecology, 1989), a review of current legal requirements (Uzych, 1990), public health implications of medical waste (Rodenbeck & Lichtveld, 1990), occupational exposure to infectious waste (Turnberg & Frost, 1990), current practices and risks posed by infectious waste disposal (Turnberg, 1991), and medical waste practices in small facilities (Byrnes & Burke, 1992). Although an earlier study about infectious waste disposal was conducted in AHA hospitals, only seven percent of US hospitals were represented in this study (Rutala, Odette & Samsa, 1989). Since that time regulations have expanded and changed. Information is still lacking about the regulations hospitals follow with regard to medical waste management, and about specific waste handling practices and disposal methods that are used to comply with federal and state mandates. No studies, to date, have investigated the medical waste practices of hospitals in the contiguous states of EPA's Region X district.

## **Purpose of the Study**

The two main purposes of this study were: (1) to investigate medical waste practices in hospitals in Oregon (OR), Washington (WA), and Idaho (ID) (EPA Region X); and (2) to gather and compare information about medical waste treatment techniques used by hospitals in these three states.

## Research Questions

The following four research questions were used to guide the study:

- 1) Which guidelines (federal or state, EPA, CDC, or OSHA) do hospitals follow in their medical waste management plans?
- 2) What is the volume of medical waste and infectious waste produced?
- 3) How is medical and infectious waste handled within facilities before final treatment and disposal?
- 4) Which technique(s) is(are) most frequency used for medical waste treatment by the hospitals in this region?

## Significance of the Study

The results from this study will assist in the identification of problems that arise in the definition and regulation of medical and infectious waste in hospitals. This research will also provide much needed documentation about the treatment techniques that are currently in use, and the amount of waste being treated by hospitals in these three states.

It is also expected that the information obtained from this study may be useful to other hospitals outside this region. Hospitals listed in *the 1992 AHA Guide for Healthcare Field* represent the majority of hospitals in the Pacific Northwest region, and must follow state laws or EPA guidelines pertaining to medical waste management. The results from this study will be shared with EPA Region X, and other regional offices and state agencies that are involved in the regulatory processes, with interested hospitals, and with waste management companies.



## Limitations of the Study

Limitations of this study include:

- 1) Data in this study are limited to that provided in the questionnaires
- 2) The study population was limited to hospitals listed in *the 1992 AHA Guide to the Healthcare Field*, and the results are not generalizable to hospitals outside the area studied.

Also, even though much medical waste is generated from physicians' offices, dental clinics and other health care facilities, data regarding this waste was not included in this study.

## Definitions

*Accreditation:* "A voluntary process recognized as a measure of quality. It is used by some regulatory agencies as one criteria for granting certification and licensure. Standard for accreditation may be similar or identical to standard for licensure. Accreditation organizations are usually based on peer approval, voluntary quality control, education, and consultation" (National Research Council, 1989).

*Biosafety level 4 disease waste:* "waste contaminated with blood, excretions, exudates, or secretions from humans or animals who are isolated to protect others from highly communicable infectious diseases that are identified as pathogenic organisms assigned to biosafety level 4 by the CDC, NIH, biosafety in microbiological and biomedical laboratories current edition" (70 RCW: chapter 70.95 K)

*Disposal:* the final placement of medical waste in designed disposal sites

*Generators:* hospitals that produce medical waste

*Half-life:* period of time during which half of the amount of radioactive isotope originally present is transformed by radioactive decay into another isotope

*Hauler:* a person or company involved in the off-site transportation of medical waste

*Infectious agents:* any microorganisms that can cause adverse effects to human or produce infection

*Infectious waste:* any medical waste that can cause adverse effects to human, and is required by laws or suggested by guidelines or standards to be handled and treated by special methods

*Labels:* words or signs that are used to identify containers of untreated waste in hospitals such as "infectious waste", "medical waste", "universal biohazard symbol", "radioactive symbol", and "hazardous waste type symbol"

*Medical waste:* waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, including regulated waste from laboratory and testing procedures; and certain types of hazardous waste and household waste produced in the hospitals

*Sanitary landfill:* "an engineering means of disposing of solid waste on land by spreading the waste in layers, compacting it into the smallest practical volume, and then covering it with soil at the end of each working day" (Koren, 1991)

*Scintillation cocktail:* any chemical solvents that contain small amounts of radioluminescent material

*Secondary sewage treatment:* one of the conventional sewage treatment methods that consists of some types of biological oxidation used to reduce solids and Biological Oxygen Demand (BOD) present in the effluent

*Segregation:* waste separation at the source of its generation

*Storage:* a temporary holding of medical waste before treatment or transport to another place or disposal

*Treatments:* any methods, techniques, or processes designed to change the biological and/or chemical character of any medical waste to decrease or eliminate its potential for causing disease

### **Abbreviations**

AHA	American Hospital Association
AIDS	Acquired Immunodeficiency Syndromes
AMA	American Hospital Association
APIC	American Practitioner of Infection Control
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	Best Available Control Technology
BOD	Biological Oxygen Demand
CDC	Centers for Disease Control
CFR	Code of Federal Regulation
EPA	Environmental Protection Agency
ETD™	Electro-Thermal-Deactivation™
FR	Federal Register
HBV	Hepatitis B Virus
HIV	Human Immunodeficiency Virus
HSC	Health and Safety Commission
ID	Idaho
JCAHO	Joint Commission on the Accreditation of Healthier Organization
LAER	Lowest Achievable Emission Rate

LLRW	Low Level Radioactive Waste
LSC	Liquid Scintillation Cocktail
LWRA	London Waste Regulation Authority
MWTA	Medical Waste Tracking Act
NA	Non-attainment Area
NAAQS	National Ambient Air Quality Standards
NIMBY	<i>Not-In-My-Back-Yard</i>
NRC	Nuclear Regulatory Commission
NSPS	New Source Performance Standard
OAR	Oregon Administration Rules
OR	Oregon
ORS	Oregon Revised Statute
OSHA	Occupational Safety and Health Administration
PSD	Prevention of Significant Deterioration
RACT	Reasonable Available Control Technology
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SD	Standard Deviation
SHSA	Society for Hospital Epidemiology of America
SIP	State Implementation Plan
WA	Washington
WHO	World Health Organization

## **Chapter II**

### **REVIEW OF LITERATURE**

#### **Regulations, Standards, and Guidelines for Medical Waste Management**

The management of medical waste is affected by numerous regulations, standards, and guidelines. Regulations are different from standards and guidelines, in that they are mandatory rules issued by either federal or state agencies. Usually, standards may be set by federal agencies or professional organizations, although they appear to be voluntary in nature, often must be adopted by a facility if the facility desires certification. In contrast, guidelines are recommendations that are issued by governmental agencies and professional organizations. Guidelines are not mandatory unless they are required by laws. (Reinhardt & Gordon, 1991). Most healthcare facilities, therefore, must comply with federal and state regulations as well as professional certification standards. This section will review guidelines, federal and state regulations, and standards involving medical and infectious waste management.

#### ***EPA Guidelines for Infectious Waste Management***

The EPA has attempted to regulate medical waste since 1976. According to 40 CFR part 250, the EPA proposed federal hazardous waste guidelines and regulations under subtitle C of Resource Conservation and Recovery Act (RCRA) of 1976. In this act, infectious waste was listed as one characteristic form of hazardous waste. However, after receiving and carefully considering public comments, the EPA decided not to include infectious waste in the RCRA regulation when it was promulgated in 1980 (US. General Accounting Office, 1990). Instead, in 1986, the EPA, Office of Solid Waste published

guidelines for the management of infectious waste which were effective in June 1986 (US EPA, 1986). Four main topics were addressed in these guidelines. First, the EPA recommended that facilities have a person or committee responsible for preparing an infectious waste management plan. Second, the EPA defined infectious waste and categorized it into six mandatory categories and four optional categories for regulatory purposes. The EPA left the decision to include the optional categories of infectious waste to a responsible person at each facility. Third, current treatment techniques were also discussed. The EPA not only described each techniques, but also suggested treatment techniques for each mandatory and optional category of infectious waste. Finally, facilities able to treat their own waste were asked to monitor their waste and determine the effectiveness of each treatment technique used (US. EPA, 1986).

### ***Medical Waste Tracking Act of 1988 (MWTa)***

Several incidents related to medical waste spurred Congress to pass the MWTa in November, 1988. The purpose of this law was to require the EPA to establish a two-year demonstration program in certain states by adding Subtitle J to the RCRA (Cross, Hesketh, Rykowski, 1990; Fay, Beck & Kessinger, 1990). Subtitle J--Demonstration Medical Waste Tracking Program--required the EPA to promulgate specific regulations on the management of infectious waste. The EPA was also required to submit two interim reports, and one final report to Congress.<sup>1</sup> On March 24, 1989, the EPA issued standards for the tracking and management of medical waste, or 40 CFR part 259 (US. EPA, 1990; PL 100-582).

The demonstration program was designed to provide an accurate picture of the amount of medical waste produced and disposed of in the states participating in the

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<sup>1</sup> At this time the first and second interim reports of the Demonstration Medical Waste Tracking Program have been submitted to Congress.

program (Connecticut, New York, New Jersey, Rhode Island and the Commonwealth of Puerto Rico). As a starting point, the EPA defined important terms which were used throughout the program, and established standards for those entities generating medical waste, and on-site incinerators. Moreover, to ensure that all medical waste in covered states was tracked, all transporters were required to fill out tracking forms. Transporters of medical waste were also required to keep records, and to transmit these data to the EPA. Finally, the standards addressed treatment, destruction, and disposal facilities. Destination facilities and intermediate handlers were also required complete tracking forms to be returned to the generator. With all these requirements, the EPA expected that medical waste could be adequately tracked and that the agency the EPA could gather data and write reports to Congress as required by the Act.

### ***CDC Recommendations***

The EPA was not the only federal agency which proposed standards or guidelines for medical waste management. There were also many related agencies and organizations that responded to this issue. Due to the high prevalence rate of HIV and HBV transmission in health-care workers, the CDC published the recommendations regarding the prevention of HIV transmission in health-care settings or "universal precautions". In the section of the universal precautions dealing with infectious waste, the CDC suggested that special care be exercised in the handling and disposal of infectious waste (CDC, 1987). A year later, the CDC issued an update to the universal precautions. It recommended that in medical waste management policies health-care settings should be in accordance with state and local regulations (CDC, 1988).

### ***OSHA Standards***

Another agency, OSHA, is mostly concerned with occupational exposure to medical waste. OSHA promulgated the final rules pertaining to occupational exposure to blood-borne pathogens in December, 1991. In response to the health risk of exposure to infectious materials or blood containing blood borne pathogens such as HIV and HBV. In these regulations, OSHA required that all employers and employees comply with the universal precautions issued by the CDC. To prevent the contact with blood or other infectious materials OSHA required special containment for both sharps and other waste. OSHA recommended that all used needles or sharps be disposed of in their entirety not sheared, bent, broken, recapped, resheated by hand, or removed from syringes (FR., 1991). Regulated waste was to be put in containers which were closable, leak-proof during handling, storage, transport and shipping; labeled or color-coded; and closed before being removed. Unlike other regulated waste, sharps had to be discarded immediately in the special puncture resistant containers that also met requirements listed above. OSHA recommended that all regulated waste be disposed of in accordance with any federal state regulations (29 CFR part 1910.1030)

### ***Nuclear Regulatory Commission (NRC)***

Most radionuclides, used in biomedical research or diagnosis of diseases, emanate low-levels of radioactivity. The agency responsible for regulating these radionuclides is the Nuclear Regulatory Commission (NRC). The NRC estimated that over 10 million nuclear medical procedures are performed annually (FR, 1986). As a result the disposal of low level radioactive waste has significant consequences for the public and environment. In 1981, the NRC issued the Biomedical Waste Disposal Regulation, which allowed NRC



licensees to store radioactive liquid scintillation and animal carcasses regardless the level of radioactivity present, until safe levels of radiation remained. The scintillation and animal carcasses could then be disposed of in a conventional manner. This rule significantly decreased the use of limited land burial facilities for highly radioactive waste by providing an alternative method of disposal for radioactive biomedical waste (FR., 1981). Moreover, the NRC also proposed Procedures and Criteria for On-Site Storage of Low Level Radioactive Waste (LLRW), due to increasing of health and safety concerns about on-site LLRW, and the inability to handle LLRW in some disposal facilities (FR., 1993). Hospitals must also comply with the regulations and rules issued by the NRC.

### ***The Joint Commission on the Accreditation of Health Care Organization (JCAHO) Standards***

Unlike regulations, standards are usually established by professional organizations. Although health care facilities can choose whether or not to adopt these standards for their facilities, they may have to meet all requirements to achieve accreditation or certification. The JCAHO, for example, annually publishes standards in the "Accreditation Manual for Hospitals". In this manual, there are several sections relevant to medical waste disposal in hospitals. According to the Infectious Control (IC) section, and the Plant, Technology, and Safety Management (PL) section, the JCAHO requires that hospitals achieve the following standards (JCAHO, 1993):

#IC.1.3.2.1.2 filled infectious containers to be disposed of in a timely manner in accordance with the hospital's hazardous materials and waste programs

#IC.5.1.3 There are written policies and procedures for the reuse of disposal items.

#PL. 1.6 There is a hazardous materials and waste programs, designed and operated in accordance with applicable law and regulation, to identify and control hazardous materials and wastes; the program includes

#PL.1.6.1 policies, procedures, and written criteria of identifying, handling, storing, using, and disposing of hazardous materials from receipt through use and hazardous waste from generation to final disposal;

#PL.1.6.2 education of personnel in accordance with SE.1 through SE.4.4 and, as appropriate, monitoring of personnel who manage and/or regularly come into contact with hazardous materials and/or waste;

#PL.1.6.3 monitoring of compliance with the program's requirements;

#PL.1.6.4 evaluation of the effectiveness of the program. As part of the hospital wide information collection and evaluation system (see PL.1.3.1), a summary of the evaluation, including identified problems, failures user errors, and relevant published information about environmental and occupational hazards, is reviewed by the safety committee.

### ***State Rules and Regulations***

As of this date 45 states have their own regulations which define infectious waste and require medical waste to be managed properly (O'Neale, 1992). The regulations and requirements for medical waste management in three states, OR, WA, and ID are pertinent to this study, and are summarized below.

#### ***Oregon***

Following the MWTa of 1989, the Oregon legislature passed a bills, known as Chapter 763, Oregon Law, 1989, codified as 459.386-459.405 which defined and prescribed the requirements for the collection, transportation, storage, treatment and disposal of infectious waste. The purpose was to protect the public health safety, and welfare, and to protect the health and welfare of workers who handled such waste. In addition, in the Oregon Administration Rules (OAR) issued in 1991, there are two chapters, which pertain to infectious waste management. OAR 333-18-040 (1991), discussed in Chapter 333, Division 18-Health Division, defines the terms related to infectious waste, and recommends suitable storage and treatment of this waste. OAR 860-66-160 to 166 (1991), discussed in Chapter 860, Division 66-Public Health Utility

Commission, focuses on the transportation and tracking documents for infectious waste in Oregon. In the state of Oregon, the Health Division generally handles issues about the definition, storage and treatment of infectious and medical waste, whereas the Department of Environmental Quality is responsible for the disposal of this waste.

### *Washington*

In Washington, Chapter 70.95K0.10 in Revised Code of Washington (RCW) established a uniform biomedical waste definition (70 RCW, 1992). Although this statute did not prescribe biomedical waste management requirements, it authorized the Department of Health, in consultation with the Department of Ecology and the local health departments, to evaluate the public health and environmental impacts of biomedical waste treatment technology. In addition, several local health departments in Washington had already adopted biomedical waste management requirements. Two statutes were involved in incinerator requirements. Chapter 70.95D RCW, Solid Waste Incinerator and Landfill Operators, required that all owners or operators had to employ only incinerators that had been certified by the Department of Ecology. Another statute was RCW 70.95.710, Incineration of Medical Waste. This required all medical waste incinerators to be conducted so that no visible combustible materials were left in ash (Washington Department of Ecology, 1993).

### *Idaho*

In 1990 the Bureau of Facility Standards, Department of Health and Welfare issued "Rules, Regulations and Minimum Standards for Hospitals in Idaho" (Idaho Department of Health and Welfare, 1990). All hospitals in Idaho must follow these rules,

containing several sections regarding infectious waste management. Infectious waste was broadly defined and categorized. These rules also described treatment, storage and disposal methods for infectious waste. In addition, hospitals were required to handle and dispose of infectious waste according to other applicable guidelines and recommendations of the CDC.

### ***National Regulations Related to Air Pollution Control***

Historically, the first regulation related to medical waste management was the Clean Air Act of 1963. A series of air regulations followed: the Air Quality Control Act of 1967, the Clean Air Act Amendment of 1970, 1974, 1977, and the latest, that of 1990. The Clean Air Acts had a significant effect on-site incineration techniques at hospitals in most communities.

The Clean Air Act of 1970, required the EPA, to specify air quality control regions. These control regions depended on geographic and other factors affecting air quality in each area regardless state boundaries. Also the EPA developed air quality criteria for significant air pollutants, such as sulfur oxides, nitrogen oxides, hydrocarbon, carbon monoxide, and particulate matters. These criteria, provided information about the levels of pollutants known to cause adverse effects to public health, welfare and environment, and about control techniques for these pollutants.

A National Ambient Air Quality Standard (NAAQS) was developed which gave the maximum level or safety level allowed for each pollutant. There were two types of standards: primary and secondary. The primary standards were based on the protection of public health whereas, the secondary standards protected the welfare and environment. Both primary and secondary standards were applied to all control regions. Moreover, in

order to enforce their own air quality control measures, states formulated their individual State Implementation Plans (SIPs) which were submitted to the EPA for approval.

New Source Performance Standards (NSPSs) were another type of standards set by the EPA which were required by the Act. These standards were different from the NAAQS because, generally, they applied to new or modified sources of pollution. NSPS contained direct air emission limitations for all major pollution from specific sources. The EPA provided all procedures for states that choose to adopt them.

States and point sources of pollutants were also required to monitor levels of air pollutants, and to keep records, which also required that they submit these records to the EPA and make them available to the public. In addition, all SIPs were monitored by the EPA. This procedure ensured the effectiveness of air pollution control in each state. For states which failed to implement SIPs, the EPA, either partially or completely, assumed responsibility for pollution control effort. Furthermore, in accordance with the Act, any citizen could levy a civil suit against a point pollutant source, state, Administrator, or the EPA, in the case that any sources violate emission standards, or when the EPA failed to implement such standards (Dutta, 1990).

In 1977 and 1979, two Amendments of the Clean Air Acts were adopted, to make the Acts more stringent and economically sound. Prevention of Significant Deterioration (PSD) was the result of both amendments. The limits for PSD were applied to all point sources, even those in areas that already had acceptable air quality. The second measure provide for Non-attainment Areas (NAs). These were the areas that failed to attain compliance with NAAQS. All new sources of pollutants in these areas had to comply with stringent requirements, such as using pollution control equipment to ensure the Lowest Achievable Emission Rate (LAER). In addition, for existing sources in NAs, the adoption of the most Reasonable Available Control Technology (RACT) was required. The last measure was a controlled-trading program established in the Amendment of 1977. The objective of this measure was to provide economic incentive systems for the recent

technology-based regulations with which all point sources had to comply. There were three major elements in this program: a bubble policy, which allowed point sources to control their emissions as a whole instead of meeting individual point source requirements; an offset policy, which allowed for inclusion of another pollutant for additional control; and a banking and brokerage policy, which allowed point sources to deposit pollution reductions for future use or sell (Dutta, 1990).

The Clean Air Act Amendment of 1990 was the newest piece of air pollution control legislation. For the first time, economic policies were incorporated into environmental regulations. In order to control the major threats to human health and the environment, acid rain, urban air pollution, and toxic emissions, the following themes were included in this Amendment (U.S. EPA, 1990):

- encourage the use of market-based principles and other innovative approaches, such as performance-based standards and emission banking and trading;
- provide a framework from which alternative clean fuels will be used by setting standards in fleet and a California pilot program that can be met by the most cost-effective combination of fuels and technology;
- promote the use of clean low-sulfur coal and natural gas, as well as innovative technologies to clean high sulfur coal through the Acid Rain Program;
- reduce energy waste and create a market for clean fuels derived from grain and natural gas to cut dependency on oil imports by one million barrels/day;
- promote energy conservation through an Acid Rain Program which gives utilities flexibility to obtain needed emission reductions through programs that encourage customers to conserve energy.

Most of this Amendment was focused on toxic emissions, hydrocarbon and nitrogen dioxide from the tailpipes of vehicles, volatile organic chemicals from small sources such as hospital incinerators and dry cleaners' shops and hazardous disposal sites. Moreover, sulfur dioxide which causes acid rain, significant ozone depleting substance was also strictly regulated (Dutta, 1990).

## **Medical Waste Characteristics**

To date, it is widely accepted that waste management in hospitals is a critical issue, not only because of its public and environmental health aspects, but also because of its business aspects. Hospitals must know the volume and types of waste they generate. Some states require hospitals to implement waste management policies. To have suitable on-site treatment techniques, accurate volume and types of waste must be determined. Also, in the case that hospital administrations decide to use off-site treatments, the cost of services from contracted facilities will depend on the amount and types of waste (Cross et al., 1990). Tieszen and Greenberg (1992), estimate that the medical waste disposal market may become a five billion dollar industry by 1994. The overall volume of waste is growing by four percent annually, approximately from 3.9 million tons in 1991 to 4.9 million tons in 1996 (Anonymous, 1992). This section provides a review of definitions and categories of medical and infectious waste, and an average amount of waste in hospitals.

### ***Waste Definitions***

The terminology used for waste management in hospitals is neither universal nor consistent in its definition. The terms "hospital waste", "medical waste", and "infectious waste" are poorly defined and used interchangeably. Several common terms are used to define medical waste in hospitals such as "treatment-room waste", and "clinical waste" (Oliver & Watson, 1992; De Ross, 1973). According to the EPA Guide for Infectious Waste Management, many terms are also used to define infectious waste such as "infectious", "pathological", "biomedical", "biohazardous", "toxic" and "medically hazardous" (US. EPA, 1986).

In general, hospital waste is defined as "all waste, biological and non biological that is discarded and not intended for further use" (Rutala & Mayhall, 1992). It consists of infectious and biohazardous waste, non-infectious solid waste, hazardous waste, and low-level radioactive waste (Cross et al., 1990). Hospital waste is also similar to municipal waste in that it is heterogeneous in nature. However, hospital waste differ in that it includes infectious waste, and require special handling and disposal techniques as required by various guidelines and regulations (Cross, 1990).

As stated in 40 CFR 259.10, medical waste is "any solid waste which is generated in the diagnosis, treatment (e.g., provision of medical services), or immunization of human being or animals, in research pertaining thereto, or in the production or testing of biological. This term does not include any hazardous waste or household waste" Also, it is defined in the Society for Hospital Epidemiology of America (SHEA)'s Position Paper as "materials generated as a result of patient diagnosis, treatment, or immunization of human beings or animals" (Rutala & Mayhall, 1992). From these definitions, it is clear that infectious waste is medical waste and that both medical and infectious waste are subsets of hospital waste. On the other hand, definition or categorization of infectious waste is a difficult task for hospitals, states and related agencies.

The definition of infectious waste is crucial. Any state or organization that is responsible for this task must be concerned with the consequences of the definition. Broad definitions might increase the amount of waste generated and the costs of infectious waste management in facilities. Infectious waste can be expected to account for 6-45 % of total hospital waste depending upon the definition applied (Rutala & Weber, 1991). The cost of infectious waste disposal is approximately 6-20 times higher than that of solid waste (Wagner, 1991). Currently, there are many definitions of infectious waste which have been adopted by states, agencies and associations issuing regulations, guidelines or even recommendations for this types of special waste. As a result of the differences in



these definitions, the costs, choices of treatment technology, and health and environmental risks of infectious waste management vary between hospitals (Uzych, 1990).

The EPA, CDC, and OSHA are three federal agencies which deal directly with the infectious waste management issue. Each agency has either issued or published rules and guidelines for infectious waste management in hospitals and health care facilities. Yet, these three agencies have different purposes for establishing these rules and guidelines. The EPA published the Guide for Infectious Waste Management in 1986 in order to provide guidelines to any person responsible for infectious waste management and to be useful as a resource and reference material for state and local regulatory agencies (US.EPA, 1986). The CDC published the Universal Precautions in 1987 in order to protect health care workers from risk, not to address waste management practices (CDC, 1987; Fay, Beck, & Kessinger, 1990). Similar to the CDC, OSHA published its rules in 1991 to protect workers from occupational exposure to blood borne pathogens (29 CFR part 1910.1030).

The definitions of infectious waste vary as a result of the different purposes of organizations. Some of these definitions are shown in Table 1.

Table 1

Comparison of Infectious Waste Definitions.

<b>Organization</b>	<b>Infectious Waste Definition</b>
<b>EPA</b>	"waste capable of producing an infectious disease"
<b>CDC</b>	"waste with the potential for causing infection during handling and disposal precautions appear prudent"

Table 1, Continued.

Organization	Infectious Waste Definition
<b>OSHA</b>	"liquid or semiliquid blood or other potentially infectious materials; contaminated items that would release blood or other potentially infectious materials in a liquid or semi-liquid state if compressed items that are caked with dried blood or other potentially infectious material and are capable of releasing these materials during handling "
<b>US. National Research Council Committee</b>	"waste that contains micro-organisms capable of causing infection in a healthy, susceptible host"
<b>Health and Safety Commission(HSC) of Great Britain</b>	"waste in class A, B, and C in categories of clinical waste <sup>a</sup> "
<b>WHO</b>	"waste contains sufficient pathogens to cause diseases"

<sup>a</sup>Class A (a) Soiled surgical dressings, swabs and all other contaminated waste from treatment areas;

(b) Material other than linen from cases of infectious diseases;

(c) All human tissues (whether infected or not), animal carcasses and tissues from laboratories and all related swabs and dressings.

Class B Discarded syringes, needles, cartridges, broken glass and other sharp instruments.

Class C Laboratory and post-mortem waste other than waste included in Class A.

Hospitals categorize infectious waste in various ways. Table 2 shows several varieties of infectious waste as categorized by the EPA, CDC, OSHA, US. National Research Council Committee, HSC, WHO, AHA, and the American Practitioner of Infection Control (APIC) (US. EPA, 1986; CDC, 1987; 29 CFR 1910.1030; National Research Council, 1989; Collins, 1991; Bern & Burke, 1992). Furthermore, OR, WA, and ID have their own regulations, and categorize their infectious waste differently (see Table 3) (ORS 459.386, 1991; RCW 70.95W, 1992; Idaho Department of Health and Welfare, 1990). These categories of infectious waste are based on both current recommendations and guidelines about infectious waste management.

To understand the significance of each category of infectious waste, the following sections will elaborate common types of infectious waste according to the EPA Guide of Infectious Waste Management and MWTa of 1989 (US. EPA, 1987; PL. 100-582, 1988) as follows:

#### Isolation Waste

This is waste generated by patients who harbor infectious agents and are isolated to prevent the spread of communicable disease. This type of waste is similar to biological waste as listed in the MWTa of 1988.

#### Culture and Stocks of Infectious Agents and Associated Biological

This type of waste includes specimens, cultures from medical and pathological laboratories, cultures and stocks of infectious agents from research production of biological, including discarded live and attenuated vaccines. In addition, culture dishes and any devices used to transfer, inoculate, and mix cultures are suggested to be considered as infectious waste, also.

#### Pathological Waste

This consists of tissues, organs, body parts and body fluids that are removed during surgery or autopsy.

Table 2

Summary of Categories of Infectious Waste from Different Organizations.

Types of Waste	EPA	CDC	OSHA	National Research Council	HSC	WHO	AHA	APIC
Isolation Waste	•	• <sup>b</sup>		• <sup>c</sup>	• <sup>d</sup>	• <sup>g</sup>	•	•
Microbiological Laboratory Waste		•	•	•	• <sup>e</sup>			
Culture and Stocks and Associated Biologicals	•			•	• <sup>e</sup>	• <sup>g</sup>	•	•
Pathological Waste		•	•	•	•	h	•	•
Human Blood And Blood Products	•	•	•	•	f	h	•	•
All Sharps		• <sup>b</sup>			•		•	•
Contaminated Sharps	•		•					
Contaminated Animal Carcasses	•			•	•	•	•	•
Contaminated Equipment	opt. <sup>a</sup>							
Waste from Surgery and Autopsy	opt. <sup>a</sup>				•	•		
Dialysis Waste	opt. <sup>a</sup>					•		
Miscellaneous Laboratory Waste	opt. <sup>a</sup>				• <sup>e</sup>			

( • = category exists)

<sup>a</sup>These wastes are optional.

<sup>b</sup>Isolation waste and sharps are not listed in infectious waste categories of "Universal Precaution" but are listed in CDC Guide for the Prevention and Control of Nosocomial Infection (Reinhardt & Gordon, 1991)

<sup>c</sup>Includes only waste from patients who harbor infectious agents (National Research Council, 1989)

<sup>d</sup>All material other than linen (Collins, 1991)

<sup>e</sup>Laboratory waste other than waste in group A of HSC classification of clinical waste (Collins, 1991)

<sup>f</sup>Sharps are not mentioned in HSC classification, but being included in definition of clinical waste by London Waste Regulation Authority (LWRA) (Collins, 1991)

<sup>g</sup>Includes waste associated with infectious patients only

<sup>h</sup>Sharps and pathological waste are defined as categories of health care waste, not infectious waste (Collins, 1991)

### Human Blood and Blood Products

These include all human blood and blood products such as serum, plasma, platelets, and other blood components.

### Sharps

These consist of objects that can penetrate skin and which have been used in patient care or in medical, research, or industrial laboratories, including hypodermic needles, syringes, pasture pipettes, broken glass, scalpel blades, and broken capillary tubes.

### Contaminated Sharps

These include all discarded sharps which have come into contact with infectious agents during uses in patient care or in medical, research or industrial laboratory.

### Contaminated Animal Carcasses, Body Parts, and Beddings

These include animal carcasses, body parts and beddings that have been intentionally expose to infectious agents in research, production of biologicals, or in the testing of pharmaceuticals.

### Waste from Surgery and Autopsy

This waste includes all contaminated waste from septic cases or from clean cases that were in contact with infectious agents. Examples of these wastes are soiled dressings, sponges, drapes, lavage tubes, drainage sets, underpads and surgical gloves.

### Dialysis Unit Waste

This waste consists of materials that have been in contact with the blood of patients undergoing hemodialysis, including contaminated disposable equipment and supplies such as tubing, filters, disposable sheets, towels, gloves, aprons, and laboratory coats.

### Contaminated Medical Equipment

This type of waste consists either in entirely or part of equipment that has been contaminated by infectious agents. Example are equipment used in patient care, medical and industrial laboratories, research, and in the production and testing of certain pharmaceuticals.

### Contaminated Laboratory Waste

Waste from medical, pathological, pharmaceutical, or other research, commercial, or industrial laboratories that was in contact with infectious agents are included in this group. Examples of this types of waste are specimen containers, slides, cover slips, disposable gloves, laboratory coats, and aprons.

Because waste in hospitals is heterogeneous, besides infectious waste, there are other types of waste generated in most hospitals: chemical, radioactive, and antineoplastic or chemotherapy waste by the EPA. Even though these kinds of waste are produced in the small amount, they require special attention from hospitals regarding both federal and state regulations.

Many chemicals substances routinely used in hospitals are either hazardous or toxic. Most solvents in laboratories found in medical waste are listed as hazardous waste. According to 40 CFR part 261, the EPA defined hazardous waste as waste that exhibits characteristic of ignitibility, corrosivity, reactivity, and toxicity. Also, this waste needs special methods for handling, treatment and disposal. Table 4 lists most commonly used chemicals in hospitals facilities regarding waste characteristics (Reinhardt & Gordon, 1991).

Table 3

Comparison of Infectious Waste Categories in OR, WA and ID.

Categories of Infectious Waste	Oregon	Washington	Idaho
Isolation Waste		● <sup>b</sup>	● <sup>c</sup>
Culture and Stocks	●	●	●
Pathological Waste	●	●	●
Human Blood and Blood Products	●	●	●
Sharps	●	●	●
Biological Waste	● <sup>a</sup>		
Animal Carcasses		●	●

( ● = category exists)

<sup>a</sup> waste materials contaminated with blood or body fluids not including diapers soiled with urine or feces

<sup>b</sup> called "Biosafety Level 4 Disease Waste"

<sup>c</sup> including only contaminated items from patients known to be infected with diseases transmitted by body fluid contacts

Antineoplastic drugs and cytotoxic agents used for chemotherapy purposes are another type of medical waste which requires extra care for treatment and disposal. Examples of this waste are Chlorambucil (U305), Cyclophosphamide (U058), Daunomycin (U059), Melphalan (U150), Mitomycin (U010), Streptozotocin (U206), and Uracil mustard (U237) (40 CFR 261.33, 1992 & Vaccare et al., 1984). Both antineoplastic drugs and cytotoxic agents are expected to be mutagenic, teratogenic, and/or carcinogenic to human and animals. Therefore, although these wastes do not exhibit hazardous characteristics, all of them were listed by the EPA as discarded commercial chemical products which are hazardous waste when being discarded or attempted to be discarded (40 CFR part 261.33 (f), 1992).

Another type of medical waste which is needed the special attention from hospitals is radioactive waste. Most radioactive waste generated in hospitals is LLRW. It was defined in the Low Level Radioactive Waste Policy Act of 1980 as "radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or by product material as defined in section 11 e. (2) of the Atomic Energy Act of 1954" (PL 96-573-94, 1980). There are three classes (A-C) of radioactive waste defined by type, concentration, and half-life of radionuclide in waste (10 CFR part 61). However, mostly radioactive waste generated in hospitals belongs to class A which are lowest concentration and have the shortest half-lives (Hendee, 1993). Hospitals utilize radioactive isotopes in diagnosis procedures, such as nuclear medicine, radioimmunoassays, therapy, and research Table 5 demonstrates half-lives and sources of radioisotopes most used in hospitals (US. EPA et al., 1991, Welch et al., 1988). In addition, radioactive waste are categorized into four different types (Reinhardt & Gordon, 1991):

*Dry waste:* It includes disposable gloves, aprons, and bench top covers; paper, glass, plastic; emptied containers contaminated with radioisotopes.

*Biological waste:* It consists of animals carcasses, organic tissues containing radioactive materials. These are mostly generated from research facilities.

*Liquid waste:* There are two types : Liquids Scintillation Cocktail (LSC) and vials, and other liquids. LSC is used to measure very low-level of radioactivity by mixing samples and cocktail in plastic or glass vials and then, placing in the counter. Other liquids are some organic solvent-based liquid waste containing radioactivity which is not LSC.

*Sealed sources and targets:* These sources are either used in radiation therapy to treat cancer or used in the machine for diagnostic purposes (FR., 1986). Waste from this sources tends to be very high activity compared with other LLRW.



Table 4

Common Hazardous Waste Generated by Hospitals.

Waste Characteristics	Substances
<b>Solvents</b>	Acetone, Benzene, Chloroform, 1,4-Dioxane, Ethanol, Ethyl ether, Formalin, Hexane, Isopropanol, Methanol, Methyl ethyl ketone, Methylene chloride, Pentane, Petroleum ether, Tetrahydrofuran, Toluene, Xylene, Carbon tetrachloride, Ignitable liquid
<b>Acids/Bases</b>	Acetic acid, Hydrochloric acid, Nitric acid, Perchloric acid, Sulfuric acid, Oleum, Ammonium hydroxide, Potassium hydroxide, Sodium hydroxide
<b>Non-specific Waste</b>	Corrosive liquid; Corrosive solid; Oxidizer, corrosive liquid; Oxidizer, corrosive solid; Oxidizer; Poisonous liquid, Poisonous solid; Corrosive, poisonous liquid; Poisonous, corrosive solid; Poisonous, oxidizing liquid; Poisonous, oxidizing solid, Hazardous waste, liquid; Hazardous waste, solid

***Waste Generation***

Most types of health care facilities generate medical waste. According to the survey of the EPA, documented in the First Interim Report to Congress as required by the MMTA, hospitals comprise only two percent of all medical waste generators, but generate as much as 77 percent (8400 lb./month/hospital) of the total volume of US regulated medical waste, annually. The remaining 95 percent consist of clinics, laboratories, physicians' offices, dentists' offices, veterinarians' offices, long-term health care facilities,

Table 5

Radioisotopes Commonly Used in Hospitals.

<b>Radioisotopes</b>	<b>Half-life</b>	<b>Sources<sup>a</sup></b>
<b>Barium-137m</b>	2.5 min.	CL
<b>Calcium-45</b>	163 d	R
<b>Carbon-14</b>	5730 y	R
<b>Cesium-137</b>	30 y	NM, S
<b>Cobalt-57</b>	270 d	L
<b>Cobalt-60</b>	5.3 y	NM, S
<b>Cromium-51</b>	28 d	R
<b>Gallium-67</b>	3.3 d	NM
<b>Hydrogen-3</b>	12.3 y	CL, NM, R
<b>Indium-111</b>	2.8 d	NM
<b>Iodine-123</b>	13 hr.	NM
<b>Iodine-125</b>	60 d	CL, NM, R, S
<b>Iodine-131</b>	8 d	NM
<b>Iridium-192</b>	74 d	S
<b>Molybdenum-99</b>	2.8 d	NM
<b>Phosphorous-32</b>	14 d	R
<b>Sulfur-35</b>	87 d	R
<b>Technetium-99m</b>	6 hr	NM
<b>Thorium-201</b>	3 d	NM
<b>Xenon-133</b>	5.3 d	NM
<b>Yttrium-169</b>	32 d	NM

<sup>a</sup> CL = Clinical Laboratory

NM = Nuclear Medicine

R = Research

S = Sealed sources

free-standing blood banks, funeral homes, and others. The amount of infectious waste in hospitals may vary in other studies, depending upon the type and size, occupancy rate, in-

and out-patient ratio, geographical location, state and local waste handling regulations, and hospital waste disposal policy (US. Department of Health Human and Services, 1990; Wagner, 1991).

There have been many survey studies conducted to estimate the amount of infectious and medical waste generated by hospitals. For example, Cross (1990) reported that hospitals generated 18-25 lb./bed/day of waste which consists of 2-3 lb./bed/day of infectious waste. This number does not include hazardous and radioactive waste, also commonly generated in hospitals. Other studies, which have produced results supporting these findings, are Rutala, Odette & Samsa (1989), and Rutala and Mayhall (1992). Both studies found that between 5-15 percent of waste generated in hospitals was infectious waste, a median of 1.38 lb./bed/day.

### **Waste Handling, Treatment, and Disposal Methods**

Once medical materials in hospitals have been discarded, waste handling procedures begin. Objectives of these procedures are to achieve a free flowing path for the movement of waste from generation to disposal and to minimize risks to personnel, (Cross et al., 1990). These waste handling procedures usually include segregation, packaging, labeling, and storage. Then, either administrators or another responsible person must decide upon the treatment and disposal methods for this waste. This section reviews and describes the most important techniques and strategies which are required by law, or are suitable for medical waste management, treatment and disposal techniques.

### ***Segregation***

Segregation is a primary waste handling process. It helps reduce the cost of disposal and the risks of exposure to either infectious or hazardous materials from medical waste (Wagner, 1991). Health personnel dealing with discarded medical materials usually perform this procedure at the point of generation. Waste should be placed directly into containers which are prepared specially for different types of waste (US. EPA, 1986). According to 40 CFR part 259.40, hospitals must segregate medical waste into sharps, fluid waste, and other regulated medical waste. Segregation of waste reduces the amount of mixed waste which requires more complicated waste handling procedures and combinations of treatment methods (Reinhardt & Gordon, 1990).

### ***Containment and Packaging***

Medical waste should be placed only into proper waste containers in order to protect the public and waste handlers from diseases, hazards, and injuries. There are two important factors that hospitals must be concerned about when selecting types of waste containers: type of waste and waste treatment technique (US. EPA, 1986; Reinhardt & Gordon, 1990).

Three types of medical waste require specific kinds of waste containers. The first type, sharps, including syringes, needles and blades, must be discarded in impervious, puncture-resistant, rigid containers (40 CFR part 259.41; 29 CFR part 1910.1030). The second type is solid and semi-solid waste. Usually this waste is placed into plastic bags which are strong enough to prevent tearing or bursting under normal conditions of handling and use. These waste containers are also impermeable prevent spillage and leakage (40 CFR part 259.41; Reinhardt & Gordon, 1990). In the case that this solid type

of waste is either radioactive or infectious, special containers are required. For example, hospitals must separately package radioactive waste in cardboard according to the level of radioactivity present, and type of radionuclide (10 CFR part 61.56). Hospitals must discard infectious waste into red or red-orange colored bags (40 CFR part 259.41). The last type of waste is liquid waste. Normally, most liquids are poured into bottles or other rigid containers with tight lids or stoppers. Whenever possible, it is recommended that liquid waste including liquid radioactive waste be solidified by absorbent or be packaged in sufficient absorbent to prevent spillage or leakage (10 CFR part 61.56). Special containers are also required for chemical and chemotherapy waste (40 CFR part 262.30).

Hospitals are concerned with waste treatment methods when selecting waste containers. Each treatment method usually requires different packaging and containerization techniques (Reinhardt & Gordon, 1990). For example, containers of waste that will be incinerated need to be combustible, and not produce significant by-products from treatment processes. Containers of medical waste that will be autoclaved must allow saturated steam to contact materials inside. Metal containers are preferable because, unlike plastic bags, they are reusable and do not crumple after exposure to the hot steam (Dole, 1978).

### ***Labeling***

Containers of waste must be labeled. Labeling methods are specified by most waste management laws. (40 CFR part 259; 49 CFR part 172; 10 CFR part 61). It is crucial to label all waste containers since this process reduces the risk of waste exposure to waste handlers and to the public. In addition, all untreated medical waste containers must be labeled with either a biohazard symbol or word, such as "Medical Waste" or "Infectious Waste" (40 CFR part 259.44). Hazardous waste, several types of

chemotherapy waste and chemical waste must be labeled in accordance with their hazardous classes and divisions, such as explosive, poison gas, flammable solid or liquid, infectious substance, corrosive, radioactive (49 CFR part 172.400). Moreover, radioactive waste must be labeled to identify classes (A-C) of radionuclides in the waste (10 CFR part 61.57).

### ***Storage***

Storage is the final step in the waste handling process. It is performed before treatment or disposal. Theoretically, for aesthetic reasons waste should be treated as soon as possible after generation (US. EPA, 1986). However, if hospitals cannot treat or dispose of their waste immediately, several factors concerning storage of waste must be addressed to reduce risk, and to ensure safety. These factors include security, accessibility, duration of storage, storage temperature, and identification of the storage area (US. EPA, 1986; Reinhardt & Gordon, 1990). Furthermore, storage requirements for radioactive waste are more stringent than those for other types of waste because it will be stored until its radioactivity decays to the background level. These additional requirements are that each facility obtain a license from the NRC or related state agency, provide isolated additional space to hold waste during the decay period, and monitor by-product materials at the container surfaces prior to disposal (10 CFR part 61; 10 CFR part 35).

## **Waste Treatment Techniques**

Medical waste treatment techniques are clearly specified by the EPA as the methods by which biological characters of waste are changed so as to eliminate or reduce

the potential for causing damage or hazards (US. EPA, 1990). Until now, many techniques have been used or proposed as suitable methods for medical waste treatment. This section reviews and demonstrates available medical waste treatment techniques which have been used or might later be used. In addition, the advantages and disadvantages of each technique are discussed and compared with respect to regulatory requirements, relative ease of the technique, skill required by operators, applicability, efficiency of the techniques, environmental effects, and costs.

### ***Incineration***

Incineration is the most commonly used medical waste treatment technique. As reported to Congress by the ATSDR in 1990, incineration was the primary method used by hospitals with approximately 5,000 medical waste incinerators operating in the US. (US. Department of Health Human and Services, 1990). Basically, incineration changes combustible materials to be incombustible. Three crucial factors for completed combustion have to be taken into account regardless of the type or design of incinerator: temperature, time, and turbulence "three T's" (Reinhardt & Gordon, 1990; Washington Department of Ecology, 1989). In addition, the amount of oxygen provided in the combustion chamber is another factor that must be considered.

To date, there are three types of incinerators operated for waste treatment. There are several differences in design, operation and purpose among them. However, each type is expected to achieve complete combustion and to emit low levels of pollutants.

### *Controlled-Air Incinerators*

This type of incinerator is referred to as "pyrolytic, modular, or starved air" incinerator (Holme & Singh, 1990; US. EPA et al, 1990). Most of these incinerators have been installed during the past 15 years and they are available in many sizes (Cross, 1990; Washington Department of Ecology, 1989; US. EPA et al 1990). Two chambers are usually used for waste combustion. The first is a primary chamber. Waste is manually or mechanically loaded into this chamber, and then a controlled supply of oxygen is injected. The combustion in this chamber normally reduces the waste into particulate matter and volatilized particles which flow to the secondary chamber. Most volatilized particles are incinerated in this chamber when excessive-air and fuel are provided. The remaining particulate matter is also completely incinerated. Heat produced from the combustion in this chamber can be recovered. Air emission control equipment when installed captures most remaining volatilized gases and particulate matter before releasing the air from the incinerator into the environment. Ash from the primary chamber is then removed and disposed of in landfills (US. EPA et al, 1991; Reinhardt & Gordon, 1990).

### *Excessive-Air Incinerators*

This type of incinerator is also called a "multiple-chamber" incinerator. Most excessive-air incinerators were installed before 1960, and were designed to burn pathological waste in hospitals (US. EPA et al, 1991). In this type of incinerator, oxygen is provided excessively in chambers. There are two major designs of excessive-air incinerators: "in-line" and "retort" hearth incinerators. The difference between these two designs is the direction of combustion gas flow in the primary chamber, horizontal in the in-line hearth, and both horizontal and vertical (U-shape) in the retort hearth. In-line



hearth incinerators can accommodate higher volumes of waste than retort hearth incinerators (US. EPA et al., 1991).

Operating procedures for excessive-air incinerators are similar to those for controlled-air incinerators. Waste is fed manually into the preheated primary chamber. Combustion occurs in the primary chamber with the provided excessive-air. Then, gas flows through the secondary chamber in which the excessive air is provided in order to complete the combustion of volatized compounds. Ash is removed manually after the incinerator cools down. Since the waste feeding and ash removal systems are designed to be performed manually, these incinerators can be operated only intermittently or for a single batch per time (US. EPA et al., 1991).

### *Rotary Kiln Incinerators*

This type of incinerator is the most sophisticated, and can be used to burn all types of waste, including liquid and hazardous waste (Reinhardt & Gordon, 1990). Unlike the previous two types, the primary chamber of a rotary kiln incinerator is a large metal drum lined with ceramic bricks. The purpose of this design is to facilitate the mixing of burning waste in this chamber (Holme & Singh, 1990). Waste is fed mechanically into the primary chamber with provided excessive air and fuel. The rotation speed and angle of the kiln are used to control the residence time of the waste and heat. In addition, there is an auxiliary burner which helps maintain the desired combustion temperature. All moisture in the waste is volatized, and moves to the secondary chamber into which air and fuel are added until the temperature reaches about 1600°-2000°F in order to assure complete combustion.

Ash from the chamber is mechanically removed and disposed of later. The volatized gas flows to the air emission control equipment which traps pollutants before

emission into the atmosphere. Rotary kiln incinerators can operate continuously or semi-continuously because the waste and ash is usually fed and removed by a mechanical system. Also, similar to the previous designs, the heat from the secondary chamber can be used to provide hot water and steam to hospitals through energy recovery processes (US. EPA et al, 1991; US. EPA, 1990; Holme & Singh, 1990).

### ***Air Pollution Control***

#### *Contents of Medical Waste*

Due to the high proportion of plastics and metal in medical waste, medical waste incinerators were reported to produce significant amounts of pollutants, such as polychlorinated dibenzo-p-dioxin (PCDD) or dioxin, polychlorinated dibenzofuran (PCDF) or furan, carbon monoxide, acid gas, sulfur dioxide ( $\text{SO}_2$ ), and nitrogen oxides ( $\text{NO}_x$ ) to the atmosphere according to the GAO Report (US. General Accounting Office, 1990). Significant sources of these pollutants are plastics in medical waste which constitute 20 to 30 percent of the volumes of the medical waste (Hasselriis & Constantine, 1992; Washington Department of Ecology, 1989). Plastics in medical waste also contain polyvinyl chloride (PVC) and other halogenated polymers which are the source of other pollutants. For example, hydrochloric acid (HCl) or/and chlorine ( $\text{Cl}_2$ ) is generated when plastics containing halogenated organic compounds are burned.

Metals in medical waste may increase the amount of both dioxins and furans (Chang, Glasm & Capt. Hickman, 1992). Also, metals often convert directly during combustion to oxides, and are emitted as sub-micron or micron size particles. Examples of metals in medical waste are arsenic, cadmium, chromium, nickel and lead (US. EPA et al., 1991). In case of incomplete combustion, carbon monoxide and particulate materials

are produced and emitted into the atmosphere regardless of the design of the incinerator (US. EPA et al., 1991).

### *Air Emission Control System*

Air emission control devices must be added to medical waste incinerators to meet the regulatory requirements of local and state air pollution control agencies (Washington Department of Ecology, 1993). Several major types of add-on air emission control systems which may be applied to medical waste incinerators are reviewed as follows:

a) Gravity Setters Using the simplest technique and construction, the gravity setter was one of the first devices used to control particulate emission from incinerators. However, as a result of stricter emission standards, the gravity setters are no longer used for medical waste incinerators because they are unable to efficiently trap vaporized particles (Adankiewicz & Mella, 1990).

b) Centrifugal Separators (Cyclone) The centrifugal separator is used to remove solid or liquid aerosols from gas steam. This device is mostly used in the mining, metallurgical, cement and plastic industries to collect fly ash (small dust particles) (Adankiewicz & Mella, 1990).

c) Electrostatic Precipitators Electrostatic precipitators are used to collect fly ash from pulverized coal fired boilers. The high voltage version of this device is more popular, and has been used to collect both solid and liquid particulate matter from many operations (Adankiewicz & Mella, 1990).

d) Wet Scrubbers Wet scrubbers are currently the most commonly used air emission control equipment for medical incinerators (Corbus, 1992). They are easy to operate and less costly than other devices. Using the principle of diffusion wet scrubbers use large liquid droplets to capture small particles. The efficiency of the drops in

capturing the particles depends on the size of the liquid and the velocity of the gas flow. There are three common types of wet scrubbers: Venturi scrubbers, spray towers, and packed-bed scrubbers (US. EPA et al., 1991).

- **Venturi Scrubbers:** Venturi scrubbers are primarily used for particulate matter removal. The Venturi scrubber consists of converging and diverging cross-sectional areas (US. EPA et al., 1991). As the gas stream pass through the scrubber, the gas approaches the vessel the gas velocity and turbulence increase so that liquids are atomized into droplets (Corbus, 1992).

- **Packed-Bed Scrubbers:** Packed-bed scrubbers are primarily used for acidic gas removal. Thus, the Venturi and packed-bed scrubber can be installed together for higher effective control of both acidic gas and particulate matter (Corbus, 1992). Vaporized gas flows through the packed-bed, and is absorbed (US. EPA et al., 1991). In addition, sodium hydroxide (NaOH) or sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) is used with water to neutralize the absorbed acidic gas (US. EPA et al., 1991).

- **Spray Towers:** The spray tower is a very simple device. Liquid is sprayed into the device counter to the current flow of the gas steam. The smaller the droplets, the higher the efficiency of gas collection. However, this type of scrubber does not collect very small particles efficiently. Thus, this technique is not suitable for controlled-air incinerators (US. EPA et al., 1991).

e) **Fabric Filters** Fabric filters, or bag houses, are among the most popular air emission control systems. they are very efficient in removing fine particles from emissions. They consist of collections of bags which are constructed of fabric material, such as nylon or wool, hung inside a housing. The combustion gas is drawn through the fabric filters. Then, the particles are retained on the fabric, and only the clean gas is allowed to escape into the atmosphere. However, the filters must be clean to be effective, and must be

repaired when they have excessive dust cakes. (US. EPA et al., 1991; Adankiewicz & Mella, 1990).

### ***Steam Sterilization***

Steam sterilization is an oxidation process which has been applied to sterilize waste and equipment in hospitals for many years (Cross et al., 1990; National Research Institute, 1989). The principle of this technique is that steam is saturated within a pressure vessel at a temperature sufficient to kill infectious agents (US. EPA, 1986). Steam sterilizers are classified into two types. The first is an autoclave, a device which has a steam jacket surrounding the pressure chamber or vessel. There are two types of autoclave which differ in air removal techniques (US. EPA, 1986):

- the gravity displacement autoclave which uses air replacement techniques in the vessel,
- and the prevacuum autoclave which uses the vacuum technique to remove air before steam is injected into the vessel.

The second type of steam sterilizer is a retort. There is no steam jacket surrounding the vessel. This type requires additional heat to increase the temperature of the vessel wall. As a result of condensation, moisture is introduced into the waste. Retort steam sterilizers are usually designed to process large volumes of waste (Reinhardt & Gordon, 1990).

Steam sterilization is a process which is dependent on time and temperature (US. EPA, 1986). This technique requires waste to be exposed to high temperatures (240-280° F) for a significant period of time. In order to reach the required temperature, regardless of the pressure, the air in the vessel must be completely removed. In addition, waste in the steam vessel must have direct contact with the saturated steam (15 to 30 pound per square inches) (Reinhardt & Gordon, 1990). There are several factors which cause incomplete

air removal from the steam vessel, for example use of deep waste containers, use of heat resistant waste containers, and the improper waste loading (US. EPA, 1986).

Moreover, there are several factors which may interfere with the waste heating process. Excessive mass or weight of waste directly affects the heating process since the heat is absorbed in proportion to the mass weight (Reinhardt & Gordon, 1990). Other interfering factors are the low heat-conductivity and heat-capacity of waste which may pose problem in the processing on, for example, pathological waste, large quantities of animal beddings, and animal carcasses (Reinhardt & Gordon, 1990).

### ***Thermal Inactivation***

The thermal inactivation technique uses high temperatures without water, fire or steam to kill pathogens in waste and sterilize equipment in hospitals. Medical waste is placed in a preheated chamber for a significant period of time depending on the type of waste. Thermal inactivation is divided into two processes by type of waste: liquid and solid. For thermal inactivation of liquid waste type, waste is mixed and heated, and is then discharged to the sewage system. For thermal inactivation of solid waste type, waste is heated at a higher temperature for a longer time (320-380° F for four hours). Thus, as indicated in the *EPA Guide for Infectious Waste Management*, the thermal inactivation technique is less efficient than the steam sterilization technique for infectious waste treatment (US. EPA, 1986).

### ***Gas/Vapor Sterilization***

Gas sterilization is a treatment technique in which medical waste and/or equipment are exposed to higher concentrations of gaseous chemicals under the required conditions

for the recommended treatment period (US. EPA, 1986). Three kinds of gaseous chemicals are commonly used for this technique: ethylene dioxide, formaldehyde, and hydrogen peroxide (Reinhardt & Gordon, 1990). Hospitals sometimes apply this technique to sterilize large pieces of contaminated equipment, which can not be moved, or which may be damaged by heat or hot steam, and waste that must be sterilized in situ (US. EPA, 1986). However, gas sterilization is not recommended by the EPA because both formaldehyde and ethylene dioxide are listed as hazardous chemicals, and are possible human carcinogens (29 CFR, part 1910.1047; 29 CFR, part 1910.1048; 40 CFR, part 355). In addition, waste and equipment made from either rubbers or plastics usually absorb these gases, and slowly release them after treatment, leading to environmental and occupational exposure problems (Reinhardt & Gordon, 1990).

### ***Hydropulping (Mechanical/Chemical Disinfection)***

Hydropulping is another oxidation technique used to treat medical waste in hospitals. Solid and liquid waste can be mixed together. Waste is shredded and pulverized by a hammer mill and then, sprayed with disinfected agents, usually chlorine (Cross et al., 1990; US Department of Health and Human Services, 1990). With this technique, the volume, but weight, of solid waste is reduced by 30 percent. The ground solid waste is then disposed of in landfills. The chlorine in the liquid waste is extracted before discharge into the sewage system (Lapierre & Jette, 1992; Cross, 1990).

### ***Irradiation***

Irradiation is a technique that is seldom used to treat medical waste and equipment in hospitals today. When it is used, two types of radiation sources are utilized. First is an

ultraviolet (UV) light source. The UV light can sterilize only the surface area because it cannot penetrate most materials (Reinhardt & Gordon, 1990). The second source of radiation is Cobalt-60. Gamma rays emitted from Cobalt-60 are able to penetrate the depth of most objects. Therefore, the latter radiation source is more frequently applied to medical waste in hospitals. However, irradiation is a very high cost technique, and requires special methods for disposal of decaying material (US. EPA, 1986; Reinhardt & Gordon, 1990).

### ***Microwaving***

Microwaving is one of the new techniques introduced into the medical waste treatment market. ABB Sanitec Inc., NJ claimed that the microwaving technique effectively reduces the disposal problems of treated medical waste (Rubin, Buckner & Boyle, 1991). Waste is crushed, shredded and steam-moistened so that it is reduced small wet particles. Using this method, the volumes, but not weight, of waste is reduced but a ratio of 8:1 (Cross et al., 1990). Then, the small wet particles are carried to the microwave unit which consists of microwave coils controlled by a temperature sensor. In this unit, waste particles are cooked and disinfected for about 30 minutes (134°C). The resulting crushed materials are disposed of in landfills or used as fuel, the plastic content in the waste contributing to its high BTU value. Moreover, according to the President of ABB Sanitec Inc., the microwaving technique presents no air emission problems (Rubin et al., 1991; Cross et al., 1990).



### ***Electro-Thermal-Deactivation™ (ETD™ )***

Electro-thermal-deactivation™ is sometimes called macrowaving. At the point of generation, waste is placed in sealed, insulated containers. These containers which provided by the treatment company (Stericycle). These containers are later placed in a high strength oscillating electrical field generated by low frequency radiowaves. Medical waste directly absorbs the energy and heat at a temperature between 90°-100°C. Because of the insulated containers, the temperature is held for a longer time so that waste is exposed to the heat simultaneously, rather than being imposed on the surface of materials. Even though, the heating process of ETD™ is similar to that of microwaving, electrical wave lengths of ETD™ are longer (Macrowave), making the preshredding processes unnecessary. After medical waste is treated, recyclable plastics, most syringes, are separated and transported to plastics recycle companies. Other non-recyclable materials are shredded and disposed of in landfills as regular solid waste (Spaurgin, 1991; R. Johnson, personal communication, January 20, 1994).

### ***Future Treatment Techniques***

Several medical waste treatment techniques have been proposed and are recommended:

*Plasma Pyrolysis:* Plasma pyrolysis is a new application of an old technology. It is an incineration method which exposes medical waste to extreme heat. Waste is placed into a pool of molten metal in the chamber. The remains in the chamber are tapped off and solidified into glass slag substances which could generate another form of energy (Hard, 1992).

*Autoclave Inactivation:* Autoclave inactivation is a technique that has been modified to treat infectious radioactive laboratory waste. Because of volatile radioactive materials, double polypropylene bags with charcoal filters are used as waste containers when autoclaving (Stinson et al., 1991). Hydrogen peroxide solution is added to the waste containers because there is the evidence that hydrogen peroxide and the autoclave process work synergistically to reduce the steam processing time (Stinson et al., 1991).

*Destructive Distillation:* Destructive distillation is a technique in which waste is thermally distilled to produce gaseous particles. Then, these gaseous particles are burned in an energy recovery process. However, this technique has not been implemented in any hospitals to date (Cross et al., 1990).

*Sterilizer/Shredder Unit:* This technique has not been tested or marketed commercially. Theoretically, by this method, waste is sterilized and shredded so as to be unrecognizable. It is possibly cheaper than other techniques. The volume of waste is reduced, and waste is changed in appearance, rendering it acceptable to many landfills (Cross et al., 1990).

*Dry Chemical Disinfection:* Dry chemical disinfection is an on-site treatment technique. Chemicals are formulated as powder and sewn in a pouch inside each red bag. Red bags are introduced into the system, sprayed with water, and shredded. Water activates the chemical in the pouches to disinfect the waste. The liquid part of the waste is discharged into the sewage system, and the solid part is disposed of in solid waste bins (Spurgin, 1991).

*Encapsulation:* This is a special technique for treatment of sharps. Small amounts of disinfectants are added into sharps containers. When enough sharps are collected, water and oxidized agents are added to the containers. The oxidizer agents react as catalysts to encapsulate the sharps in a polymer matrix. The encapsulated sharps can then be disposed of in landfills (Spurgin, 1991).

*Laser Technology:* Lasers are used to burn medical waste at temperatures between 5,000° and 10,000°F. With this high temperature, waste is melted into clean and aggregate stone. This laser technique is a derivative of a incineration which requires an air pollution control system (Spurgin, 1991).

*Electrohydrolic Disinfection System:* This system has been used for the disinfection of liquid, such as industrial waste-water discharge. Ultraviolet radiation, hydrogen, hydroxyl, ozone, shock waves, and pulsed electrical plasma which discharges in water are used to disinfected the waste (Spurgin, 1991).

## **Waste Disposal**

Generally, after proper treatment, most medical waste may be handled as normal solid waste which is usually disposed of in landfills (Reinhardt & Gordon, 1990). On the other hand, sharps, some chemical, pathological, chemotherapy, and radioactive waste are required to undergo additional processes before disposal (Reinhardt & Gordon, 1990). Several common disposal techniques are described as follows.

### ***Landfill Disposal***

Landfill disposal is the best option to dispose of general solid waste, such as incineration ash, sharps, pathological waste, red bags, and hazardous chemical waste.

*Incineration Ash:* This includes bottom and fly ash. The contents of ash residues from medical waste incinerators are as diverse as those from municipal solid waste incinerators (Hasselriis, 1992; 29 CFR part 1910.1030). Fly ash consists of lighter particles which include metal, chemicals, and is usually toxic. Unlike bottom ash, fly ash must be disposed of only in hazardous waste landfills (Reinhardt & Gordon, 1990).

*Sharps:* Although sharps are treated, they still cause injuries in disposal related workers, such as waste haulers, equipment operators, and landfill workers. Incinerated sharps may be disposed of in landfills whereas, autoclaved sharps are not acceptable in landfills because they may still cause needle-stick injuries. They must be put in closed containers or imbedded in plastic prior to disposal in general landfills or in separated area of landfills (Reinhardt & Gordon, 1990).

*Pathological Waste:* For aesthetic reasons, recognizable body parts should not be disposed of in landfills. Instead, it is recommended that all pathological waste be incinerated, transferred to a mortician for burial, or ground up and flushed into the sewage system (Reinhardt & Gordon, 1990).

*Red Bags:* Even though waste in red bags is properly treated and no longer infectious, disposal workers may still perceive the threat. Therefore, hospitals should use alternative containers for infectious waste to be steam sterilized, such as plastic bags which crumple after exposure to heat (Reinhardt & Gordon, 1990). Hospitals may also try to convince or explain to haulers and landfill operators about the safe medical waste treatment techniques practiced at their facilities.

*Hazardous Chemical Waste:* Most hospitals are conditionally exempt small quantity generators which generate less than 100 kg of hazardous waste per month of hazardous chemical waste. Hospitals can dispose of their chemical waste in EPA permitted or state-licensed hazardous waste landfills (Reinhardt & Gordon, 1990).

## ***Burial***

Burial is a suitable method of LLRW disposal (Knoche, 1991). The burial site must be designed to isolate the waste to protect both humans and the environment. The site must be located in an isolated region without earthquakes, volcanoes, or other

geological activities in order to ensure that the buried radionuclides do not leak into the soil, surface and/or ground water (Knoche, 1991).

Today, in the US, there are only a few states, Washington, Nevada, and North Carolina, that provide radioactive waste burial sites. Furthermore, these burial sites either will close in the next few years, or will increase their surcharges of waste from different states (Hendee, 1993). Therefore, burial is a very expensive disposal method which may not be applicable for many hospitals.

### ***Decay in Storage***

Waste containing radionuclides that have short half-lives may be disposed of easily after storage for a period of time long enough to allow for radioactive decays. This method requires the special packaging and labeling of waste (see waste handling section). According to 10 CFR 35.92, licensed hospitals are allowed to store LLRW for decay and dispose of it as normal waste if the LLRW contains radionuclides with physical half-lives less than 65 days under the following conditions:

- the LLRW is held for decay a minimum of ten half-lives;
- the LLRW is monitored at the container surface before disposal;
- the LLRW's radioactivity cannot be distinguished from background radiation levels;
- and all radiation labels are removed or obliterated.

### ***Discharge to the Sewage System***

In addition to blood, blood products, and body fluids, there are other aqueous wastes which are discharged into the sewage system, for example, chemical waste,

antineoplastic drugs used in chemotherapy treatments, and LLRW. Most liquid and semi-liquid waste is usually poured into the sewer. Liquids will be diluted and treated at the waste water treatment plants in each area. As required by the EPA (1986) and states, the discharge from hospitals must meet the requirements of related local sewer authorities in their areas. Today, only sewage systems that have secondary treatment methods and are not the combined sewage systems are allowed to handle discharged liquid medical waste (Reinhardt & Gordon, 1990).

### ***Evaporation***

Evaporation is a disposal method for small amount of aqueous LLRW. It is performed by placing open aqueous LLRW containers in a safe fume-hood or ventilation device. However, hospitals must have license, or obtain approval from local agencies to process LLRW in this manner. In addition, hospitals are required to monitor the release of volatile organic compounds and to meet local air pollution control requirements, especially when the LLRW contains volatile organic compounds (Reinhardt & Gordon, 1990).

### ***Selection of Medical Waste Treatment Technologies***

Many technologies have emerged since the beach wash-up event in 1988. There is no single technology that treats all types of medical waste. Each technology has advantages and disadvantages. It is crucial for hospitals to select the most suitable technologies for medical waste treatment in their facilities. Several important factors must be considered when choosing medical waste treatment technologies: regulatory requirements, operating concerns, applicability, effects of treatment on waste, occupational hazards, environmental impacts, and cost (Reinhardt & Gordon, 1990).

Table 6 shows comparisons of the factors and available techniques described in the previous sections (Reinhardt & Gordon, 1990; US. EPA et al., 1991).

Table 6

Comparison of Available Medical Waste Treatment Technologies and Important Factors Considered in Selecting Technologies

Factors	Medical Waste Treatment Technologies							
	Incineration	Steam Sterilization	Thermal Deactivation	Gas Sterilization	Hydropulping	Irradiation	Microwaving	ETD <sup>a</sup>
<b>Regulatory Requirements</b>	Air pollution control, Hazardous waste disposal, Waste water	Waste water	Waste water	Occupational exposure to toxic gases	Waste water	Decaying source disposal	Air pollution control	None
<b>Environmental Impacts</b>	Air emission, waste water, toxic ash disposal	Drained water, odor	High temperature waste water	Toxic and carcinogenic gas	High chemical compounds of waste water	Decay source disposal	Possible release of volatile materials	None



Table 6, Continued.

Factors	Medical Waste Treatment Technologies							
	Incineration	Steam Sterilization	Thermal Deactivation	Gas Sterilization	Hydropulping	Irradiation	Microwaving	ETD <sup>a</sup>
<b>Operating Concerns</b>								
- Location of operating	On/Off-site	On/Off-site	On/Off-site	On/Off-site	On/Off-site	On/Off-site	On/Off-site	Off-site
- Equipment operation	Complex	Simple	Simple	Moderate	Moderately complex	Complex	Complex	Complex
- Operator requirement	Highly skilled	Trained	Trained	Trained	Well trained	Highly trained	Well trained	Well trained
- Benefits	Energy recovery	None	None	None	Use of effluent in laundry	None	None	Recyclable materials
<b>Applicability</b>								
-Types of waste	Almost all waste	Most waste	Almost all waste, liquid preferred	Almost all waste	Most waste	Most waste	Most waste, but not body parts and animal carcasses	Almost all waste

Table 6, Continued.

Factors	Medical Waste Treatment Technologies							
	Incineration	Steam Sterilization	Thermal Deactivation	Gas Sterilization	Hydropulping	Irradiation	Microwaving	ETD <sup>a</sup>
<b>Effects of Treatment to Waste</b>								
- Volume and weight reduction	80-95% of volume and weight	30% of weight	Very little	None	8:1 of volume, adding weight	None	80% of volume, adding weight	80-95% of volume
- Waste appearance	Burned waste, unrecognizable	Steamed waste, recognizable	Heated waste, recognizable	Gas exposed waste, recognizable	Shredded and disinfected waste, unrecognizable	Irradiated waste, recognizable	Shredded and heated waste, unrecognizable	Simultaneously radiated, and shredded waste, unrecognizable
<b>Occupational Hazards</b>	Moderate	Low	Low	High	Moderate	High	Low	None
<b>Cost</b>	High	Low	Moderate		Moderate	High	Moderate	Moderate

<sup>a</sup>according to personal communication with Mr. Rex Johnson, Stericycle company

## **Chapter III**

### **METHODS**

This chapter describes methods and procedures used in this study. The study population is described in the first section. The second section describes the development and administration of the questionnaire. The third section provides information about data collection and all strategies that the researcher used to improve response rate. The last section in this chapter, data analysis, presents the statistical methods used to analyze the data.

#### **Study Population**

The population for this study included all hospitals in Oregon, Washington, and Idaho listed in *the 1992 AHA Guide for Health Care Field* (see Appendix A). The original group included 75 hospitals in Oregon, 111 hospitals in Washington, and 48 hospitals in Idaho were originally included in the study. Each hospital was called to obtain the name and the title of a person responsible for medical or infectious waste management at that facility. Five hospitals were deleted from the Oregon list for the following reasons: (1) two hospitals, a mental health hospitals and a psychiatric center, reported no regular medical waste generation; (2) one hospital in Portland did not exist; and (3) two hospitals were used as samples for the pilot study, and were not therefore included in the study population. Thus, the final list from Oregon consisted of 70 hospitals.

Four hospitals were deleted from the Washington study population: three hospitals were either psychiatric care centers or mental health institutions, and indicated that they did not generate medical waste; and one hospital in Tacoma could not be contacted because the telephone was disconnected. Thus, 107 hospitals were surveyed in

Washington state. No hospitals in Idaho were deleted from the population. A total of 225 hospitals in the three states were sent questionnaires.

### **Survey Instrument**

A four-page questionnaire composed of 12 questions was developed to address the research questions (see Appendix B). The questionnaire was revised and critiqued by staff at the Oregon State University Survey Research Center.

This questionnaire was written, organized, and designed using procedures that would help increase the response rate. Questions were constructed in three types of formats. One was "a close-ended question with ordered answer choices" which means that each choice represented a gradation of a single dimension of some concept (Dillman, 1978). Examples of this type of question are question No. 8.1, asking the time since the last incinerator was operated in the hospitals and question Nos. 11 and 12, inquiring about the amount of medical and infectious waste generated by the hospitals. Another type of question was "a close-ended question with unordered answer choices". This type was quite similar to the first one except that each choice is dependent and represents different concepts (Dillman, 1978). Most of the questions were structured in this format. The last type of question was "a partially close-ended question". This type is constructed by adding the choice "other ( please specify) " to the two types of question structures (Dillman, 1978). Many sequential questions in this survey questionnaire were written in this format such as questions 1.1, 3.1, 4, 5.1 (see Appendix B).

The questions were then grouped according to content. The first question was the most important, because it helped respondents decide whether or not they should complete the remainder of questionnaire. As stated by Dillman (1978), the first question must be easy, neutral, clear, applicable and interesting to the respondent, and related to the

purpose of the survey. The next step was to format all questions. Each of the four pages of the questionnaires was constructed carefully so that respondents would not accidentally skip any questions. The following principles were applied in formatting this questionnaire (Dillman, 1978):

- Use lower case letters for questions, upper case for answers;
- Establish a vertical flow;
- Provide directions for how to answer;
- Identify answer categories with a "hat" and showing the connection between items and answers in serial questions;
- Use the multiple columns technique to save space;
- Make questions and answers fit on the same page.

The final draft of the questionnaire for this study was pretested to improve validity and reliability by three people whose jobs were related to medical and infectious waste in hospitals: Ms. Vicki Horneck, Infection Control Nurse at Good Samaritan Hospital, Corvallis, Oregon; Ms. Pat Mason, RN of Salem Hospital, Salem, Oregon; and Mr. Steve Peters, Customer Relations of Bio-Med of Oregon. They provided many productive and helpful suggestions. After pretesting, several questions were either eliminated, changed or reordered.

### **Data Collection**

In order to achieve a high response rate, several strategies were utilized which are discussed in this section, including writing and formatting the cover and follow-up cover letters. In addition, the date that questionnaires were sent as well as the length of the waiting period before sending the follow-up letter are also discussed.

### ***Cover Letter***

The cover letter was a critical component of the questionnaire mailed survey. It previewed the purposes of the study and delivered a personal appeal to each respondent (see Appendix C). The cover letter in this survey was carefully written to address the following concerns:

- length - The letter was limited in length to one page.
- formality - The cover letter was written in a business letter form, using official the Oregon State University Department of Public Health letterhead.
- personalization and individual attention - The name and title of each respondent and date of the mailing, September 1, 1993 was individually typed onto the cover letters. Each letter was signed both by the researcher and by Dr. Anna K. Harding, the researcher's major advisor.
- confidentiality - Respondents were assured of the confidentiality of their responses. Neither the name nor institution were readily identifiable from the returned questionnaires.
- incentives to respond - Respondents were offered a summary of the results. A postage paid returned envelope was also included with each questionnaire.
- thank you and whom to contact with further questions - The researcher thanked respondents for their participation and provided information regarding whom to contact with questionnaire regarding the study.

### ***Mailing***

The cover letter, questionnaire, and return envelope were mailed to respondents by first-class mail. This added a sense of importance to the mailing. To attract attention, the researcher chose to use multicolored stamps instead of metered stamps, even though there

were no differences in the cost (Dillman, 1979). The survey materials were mailed in "4<sup>1</sup>/<sub>5</sub> x 8<sup>3</sup>/<sub>5</sub>" envelopes, which were large enough to accommodate the four-page questionnaire, cover letter, and return envelope. The envelopes were personally addressed to the respondents. The postage paid return envelope were addressed to the Chair of the Department of Public Health.

Each questionnaire was identified with a three digit number and the initial of the state of the hospital. For example, the first questionnaire from Idaho was 001I, the last one was 048I. The questionnaires from Oregon were numbered from 049O to 118O, and the questionnaires from Washington were numbered from 119W to 225W. The coded questionnaires were carefully matched with their cover letters, and envelopes. The materials to be included in the mailing were then assembled and mailed.

### ***Follow-Up Mailing***

The questions were first mailed in September, 1993. One month after sending the first round of questionnaire packets, fewer than 50 percent of the questionnaires had been returned. A second batch of surveys was sent on October 1, 1993. A follow-up letter was included, which was similar to the cover letter mailed in the previous questionnaire packets. Additional information was added to increase interest in responding (see Appendix C). For example, the first paragraph reminded respondents about the previous questionnaires. Later, the usefulness of the study and the importance of each response were presented. The rest of the contents were similar to that in the previous cover letter. However, new codes were assigned to the follow-up questionnaires to prevent any confusion. The first number of the follow-up mailing was 226 I, which followed the last number from previous mailing (225W). Then, all materials were assembled into the envelopes with multicolored first class stamps as in the first mailing.

## **Data Analysis**

All responses were collected up until November 1, 1993, a period of one month after mailing the follow-up packets. To facilitate the data entry process, the completed questionnaires were separated into groups by states.

Each response was coded for data entry. For instance, "1" represented the response "NO", "2" represented "YES", "3" represented "BOTH" or "NA" in some questions, and "0" was entered for questions that did not have any responses. After the responses were coded, all data were entered by the researcher using the computer spreadsheet program, Excel 4.0 (Microsoft Corporation, 1985). The entered data were checked for accuracy by re-examining all entries twice. These data were tabulated and organized using the same computer program.

Two statistical packages were used to analyze both qualitative and quantitative data. Qualitative data were analyzed using statistical functions in Excel 4.0 (Microsoft Corporation, 1985). Quantitative data were tabulated and analyzed using Statgraphics 5.0 (Statistical Graphic Corporation, 1985). Analysis techniques include the following: frequency analysis, percentage, summation, and the chi-square test for qualitative and categorical variables; and measures of central tendency (mean, median, and standard deviations) for the number of hospital beds in three states. The level of significance for analysis was set at  $\alpha = 0.05$ .



## **Chapter IV**

### **RESULTS AND DISCUSSION**

This chapter is divided into five sections. The first section presents general descriptive data such as characteristics of the hospitals and information about response rate. The remaining sections are directed toward answering the research questions.

#### **General Information**

Of the 225 questionnaires sent on September 1, 1993, only 110 (48.9%) were returned by the end of that month. On October 1, 1993, 115 follow-up packets were mailed to the hospitals who had not responded. This second mailing increased the response by 51 questionnaires (22.7%), for a total of 161 questionnaires.

Occupations of the persons in charge of medical or infectious waste management (as given by the telephone operators contacted at each hospital) are listed in Table 7. The majority of these people occupy positions in infection control, environmental services, nursing, maintenance, and facility personnel management.

When re-examining all returned questionnaires, two hospitals in Mount Vernon, WA and two in Centralia, WA were Affiliated Health Services and Providence Hospitals, respectively. Thus, according to the respondents, the answers were combined and only one questionnaire was returned for each. For two other hospitals in Tacoma, WA, the survey was answered by a single person who reported in one survey data for both hospitals. As a result the total hospitals in WA was three less than the actual number of questionnaires sent (107). The number of hospitals used in the calculations in the later section was also changed to 222.

Table 7

Occupations of Hospital Personnel in Charge of Medical or Infectious Waste Management.

Occupations	Oregon	Washington	Idaho	Total
Administrators and General Managers	3	5	4	12
Engineers	2	3	-	5
Environmental Services Managers	8	16	3	27
Epidemiologists	4	1	-	5
General Nurses	5	9	5	19
Housekeepers & Material Personnel	3	8	4	15
Infection Control Personnel	33	39	7	79
Laboratory Personnel	-	-	4	4
Maintenance, Plant, and Facility Managers	5	9	11	25
Medical Officers	2	1	1	4
Occupational Safety/ Risk Management Personnel	3	4	4	11
Related Waste Positions	-	2	3	5
Others <sup>a</sup>	1	9	1	11
Not Known	1	-	1	2
<b>Total</b>	<b>70</b>	<b>107</b>	<b>48</b>	<b>225</b>

<sup>a</sup>Others in Oregon: Employee Education Person.

in Washington: Contractor, Customer Resource Management, Director of Hospital Services, Director of Security, Patient Review Total Health Director, Personnel, Security Manager, Staff Development.

in Idaho: Executive Secretary.

Table 8 shows the size of hospitals in OR, WA, and ID, categorized by number of beds. Most hospital in these states were less than 300-bed hospitals. In ID, the largest hospital had 286 beds. However, when considering means and standard deviations, the standard deviation of the number of beds in hospitals in OR was higher than the mean (mean = 143, SD = 162.5) and in both WA and ID, the standard deviations were very close to their means (WA: mean = 142, SD = 138.4; ID: mean = 89, SD = 76.6). These large SDs existed because of the wide range in number of beds in these states: in OR the range was 18-771 beds; WA the range was 8-623 beds; and ID the range was 10-286 beds. Therefore, medians were also reported as an average number of beds in hospitals, which were 72, 91, and 51 in OR, WA and ID respectively.

Table 8

Number of Beds in Hospitals in OR, WA and ID.

Number of Beds	Oregon	Washington	Idaho	Total
<b>8-29</b>	2	9	7	18
<b>30-59</b>	17	17	13	47
<b>60-89</b>	10	10	2	22
<b>90-199</b>	14	21	9	44
<b>200-299</b>	1	6	3	10
<b>&gt;300</b>	9	11	0	20
<b>Total</b>	<b>53</b>	<b>74</b>	<b>34</b>	<b>161</b>

The follow-up strategy improved the response rate of this survey. 48.9 percent of hospitals returned questionnaires from the first mailing. The second mailing increased the response rate to 72.5 percent, which is very high in comparison to a 46 percent response

rate for a similar study of US hospitals conducted in 1987 (Rutala, Odette & Samsa, 1989).

As shown in Table 9, the response rates for each of the three states was similar. Hospitals in WA had an initial response rate lower than those in OR, and more questionnaires in the follow-up packets were returned from WA hospitals than other hospitals, as is illustrated in Figure 1. This may have occurred because medical and infectious waste management, including occupational exposure related to waste handling in health care facilities has recently been studied intensively in WA (Washington Department of Ecology, 1989). The response rate in this study for WA was higher than that reported in study conducted by the Washington Department of Ecology in 1989, in which 51 percent of hospitals responded a questionnaire (Washington Department of Ecology, 1989). In addition, when considering the total response rate in the current study, there was no difference between states,  $\chi^2_{0.05} = 0.4$  with  $df = 2$ .

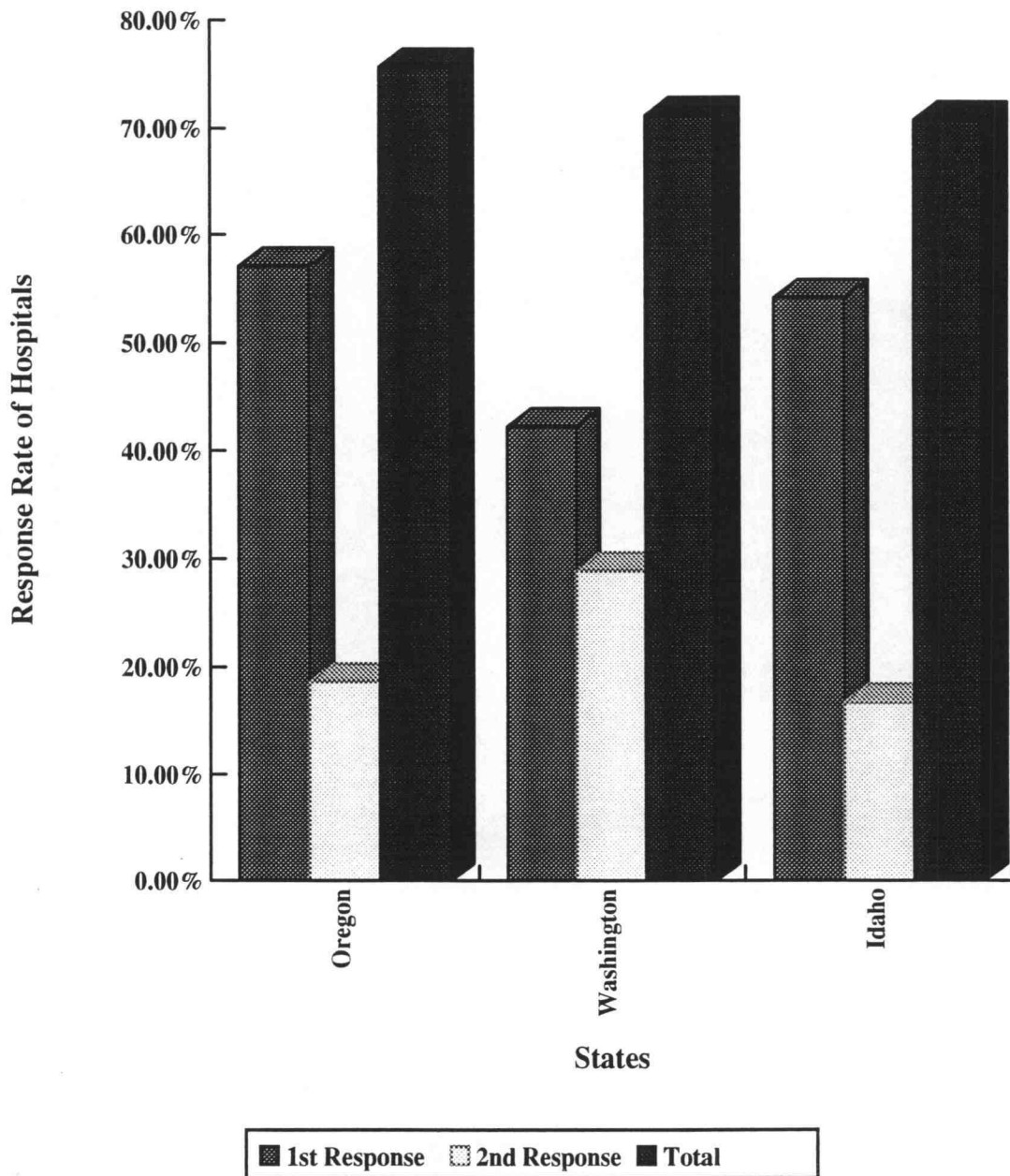
Table 9

Questionnaire Response Rates for the Three States.

States (total number of hospitals)	Returned Questionnaires (% of the total from each state)
Oregon (70)	53 (75.7 %)
Washington (104)	74 (71.2 %)
Idaho (48)	34 (70.8 %)
Total	161

Figure 1

Comparison of the First and Second Response Rates for Hospitals in Each State.



## **Guidelines for Medical Waste Management**

The first question of the survey queried hospitals about their definitions of infectious waste. Of 161 hospitals reporting, 74 ( 46.0%) adopted the term "regulated infectious waste". Forty-three hospitals (26.7%) did not answer this question. However, more than 90 percent of those that answered either "NO" or did not respond continued to work on questions 1.1 (guidelines), and 1.2 (categories of waste), which were designed for hospitals that answered "YES" in question 1 only. The term "regulated infectious waste" was suggested by one of pretested hospitals. From these data it was determined that this term was not commonly used in hospitals in these three states. On the other hand, the terms "regulated medical waste", "medical waste", "biomedical waste", "biohazardous waste", and "infectious waste" were also applied in many hospitals, according to notes from respondents. Another reason that hospitals answered the sequential questions, 1.1 and 1.2, but answered "NO" or did not answer question 1.1 might be that they were concerned about that a state regulatory agency might find them out of compliance. The analysis therefore includes all answers to questions 1.1 and 1.2, including responses from hospitals that did not answer "YES" in question 1.

The results showed 152 responses to question 1.1, asking which agencies' definitions had been adopted to define medical waste as infectious waste. One hundred thirty-seven (90.1%) used definitions from more than one organization to define infectious waste. Fifteen hospitals (9.9%) used only the state regulatory agency's definition of infectious waste. A majority (62.5 %) of hospitals indicated they used state regulations to define infectious waste. See Table 10 for a breakdown of agencies that provide definitions of infectious waste, and percentage of hospitals that used various definitions. Several used other sources for their definitions of infectious waste, such as the Department of Transportation, the Industrial and Health Administration, and the County Health Department in Washington; and the hospital's own policy.

Table 10

Sources of Definitions of Infectious Waste Used by Hospitals.

<b>Organizations</b>	<b>Number of Hospitals<sup>a</sup></b>	<b>Percentage<sup>b</sup></b>
<b>EPA</b>	46	32.3 %
<b>CDC</b>	74	48.7%
<b>OSHA</b>	95	62.5 %
<b>JCAHO</b>	61	40.1 %
<b>AMA or APIC</b>	21	13.8 %
<b>State Regulations</b>	106	62.5 %

<sup>a</sup> many hospitals chose more than one source

<sup>b</sup> percentage from 152 hospitals

The data show that hospitals may combine guidelines from many agencies to define their infectious waste. Each state has passed regulations that are at least as stringent as federal agencies' guidelines (OR Laws, Chapter 763, 1989; RCW 70.95W, 1992; Idaho Department of Health and Welfare, 1990). As shown in Table 10, however, even though hospitals follow their own state regulations, they often use other guidelines as well to define infectious waste. One reason for this is that each federal agency has issued infectious waste recommendations to serve different purposes. For example, OSHA rules are established in light of occupational exposure to bloodborne pathogens. Health care institutions must meet OSHA requirements, and in addition, must follow JCAHO and AMA standards to receive accreditation. The data indicated that 55.9 percent of hospitals in this study belong to both associations; 6.8 percent were accredited by only participating JCAHO, and 4.9 percent were only AHA members (AHA, 1992).

Question 1.2 asked respondents to select the categories of medical waste that were considered to be infectious waste in their hospitals. The most common categories of

infectious waste reported were blood specimens and blood products (96.9%), all sharps (93.7 %), microbiology laboratory waste (89.9 %), pathological waste (89.9 %), body parts (80.4 %), and waste from surgery (77.2 %) (see Table 11). These results, when compared to state agency definitions, indicate that more categories of medical waste are considered to be infectious by hospitals than are required by state regulatory agency definitions.

Although contaminated equipment is not regulated as infectious waste by state agencies, it is "optional" in the EPA definition (US. EPA, 1987), and institutions may choose to manage this waste as infectious waste due to its potential hazards. More than 50 percent of hospitals choose to designate contaminated equipment as infectious waste (see Table 11).

Chemotherapy waste is not categorized as infectious waste in either state regulations and other agencies' guidelines (ORS 459.386, 1991; RCW 70.95, 1992; Idaho Department of Health and Welfare, 1990). The data from this survey, however, indicated that 59.5 percent of hospitals in OR, WA and ID considered this waste to be infectious. One of the reasons that hospitals considered this waste to be infectious is that chemotherapy waste may contain antineoplastic drugs and cytotoxic agents, which are considered to be toxic agents due to the teratogenic, mutagenic, and/or carcinogenic effects on both human and animals (Reinhardt & Gordon, 1991). Although antineoplastic drugs are contained in the "U" list of hazardous wastes defined by the EPA, there are few references defining or discussing this waste as infectious waste (Vaccare et al., 1984). The results from this study suggest, therefore, that infectious waste in hospitals may be overly managed because chemotherapy waste is not officially classified as infectious waste.



Table 11

Categories of Medical Waste Considered to be Infectious Waste by Hospitals in Each State.

Waste Categories	Oregon	Washington	Idaho
<b>Waste from Communicable Disease Units (Isolation Waste)</b>	<b>71.2 %</b>	<b>78.4 %</b>	<b>84.4 %</b>
<b>Culture and Stock (Microbiology Laboratory Waste)</b>	<b>90.4 %</b>	<b>89.2 %</b>	<b>90.0 %</b>
<b>Pathological Waste</b>	<b>90.4 %</b>	<b>90.6 %</b>	<b>87.5 %</b>
<b>Blood Specimens and Blood Products</b>	<b>94.2 %</b>	<b>97.3 %</b>	<b>100 %</b>
<b>Sharps</b>	<b>94.2 %</b>	<b>93.2 %</b>	<b>93.8 %</b>
Only Contaminated Sharps	3.9 %	5.7 %	6.3 %
<b>Body Parts</b>	<b>84.6 %</b>	<b>78.4 %</b>	<b>78.1 %</b>
Waste from Surgery Rooms	71.2 %	78.4 %	78.1 %
<b>Animal Carcasses</b>	<b>21.2 %</b>	<b>25.1 %</b>	<b>18.8 %</b>
Dialysis Unit Waste	36.5 %	23 %	28.1 %
Contaminated Equipment	69.2 %	52.7 %	59.4 %
Chemotherapy Waste	63.5 %	59.5 %	53.1 %

Note: Waste categories and numbers in bold indicate infectious waste categories defined by state regulations.

Most hospitals are concerned about another type of infectious waste, sharps. In question 1.2, hospitals were asked whether they considered "sharps" and "only contaminated sharps" to be infectious waste. Hospitals in OR, WA, and ID chose to manage only contaminated sharps as infectious waste (3.9, 5.8 and 6.3%, respectively). While both the EPA and OSHA suggested that only contaminated sharps should be

managed as infectious waste, state regulations and the CDC strongly recommended that hospitals treat all sharps as infectious waste (see Table 2).

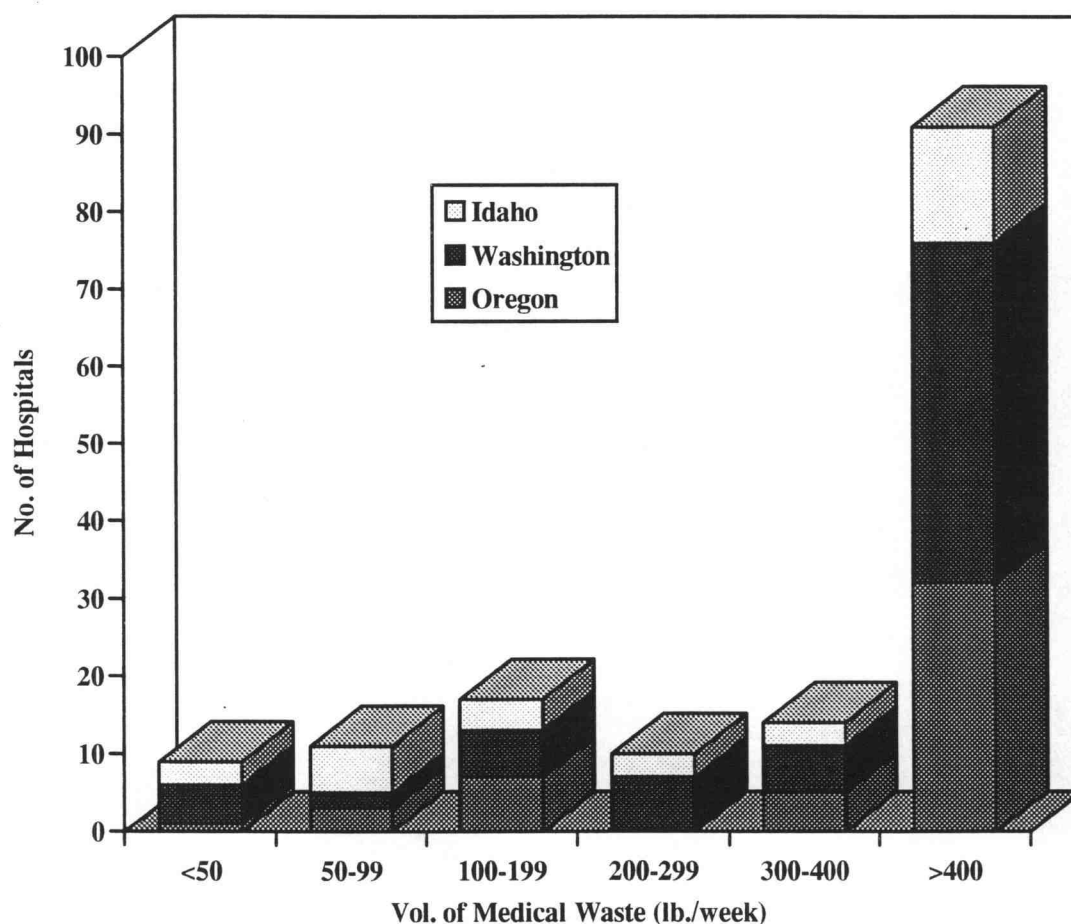
The data confirmed that sharps are closely regulated by hospitals. One reason for this may be that hospitals which manage only contaminated sharps as infectious waste may be in violation of state law. In Idaho, in particular, rules and regulations for hospitals clearly state that "infectious waste shall be handled and disposed of in accordance with the most current guidelines and recommendations of the CDC" (Idaho Department of Health and Welfare, 1990). One consequence of this inappropriate management of sharps are needle-stick injuries. As reported by Cimino (1975), each year as many as 50-100 puncture wounds were incurred as a result of handling hospital waste, waste from physicians' and dentists' offices, and discarded drug users' needles. Turnberg and Frost (1990) reported in a survey of 940 Washington state waste industry workers that 50 percent of the respondents reported having received cuts and scratches on the job, and due to the handling of infectious waste 10 percent of waste collectors experienced needle-stick injuries from waste pick up.

### **Volumes of Medical and Infectious Waste**

Questions 11 and 12 asked respondents to quantify the medical and infectious waste produced each week in their hospitals. Ninety-one hospitals generated more than 400 pounds of medical waste per week. Seventy-three hospitals generated more than 150 pounds of infectious waste per week. Thirty-eight hospitals generated between 30-150 pounds per week, and only thirty hospitals produced less than 30 pounds per week (see Figures 2 and 3). There were 16 hospitals in these states that did not know the amount of infectious waste generated in their facilities, even though 14 of these 16 hospitals were able to quantify the amount of medical waste they produced.

Figure 2

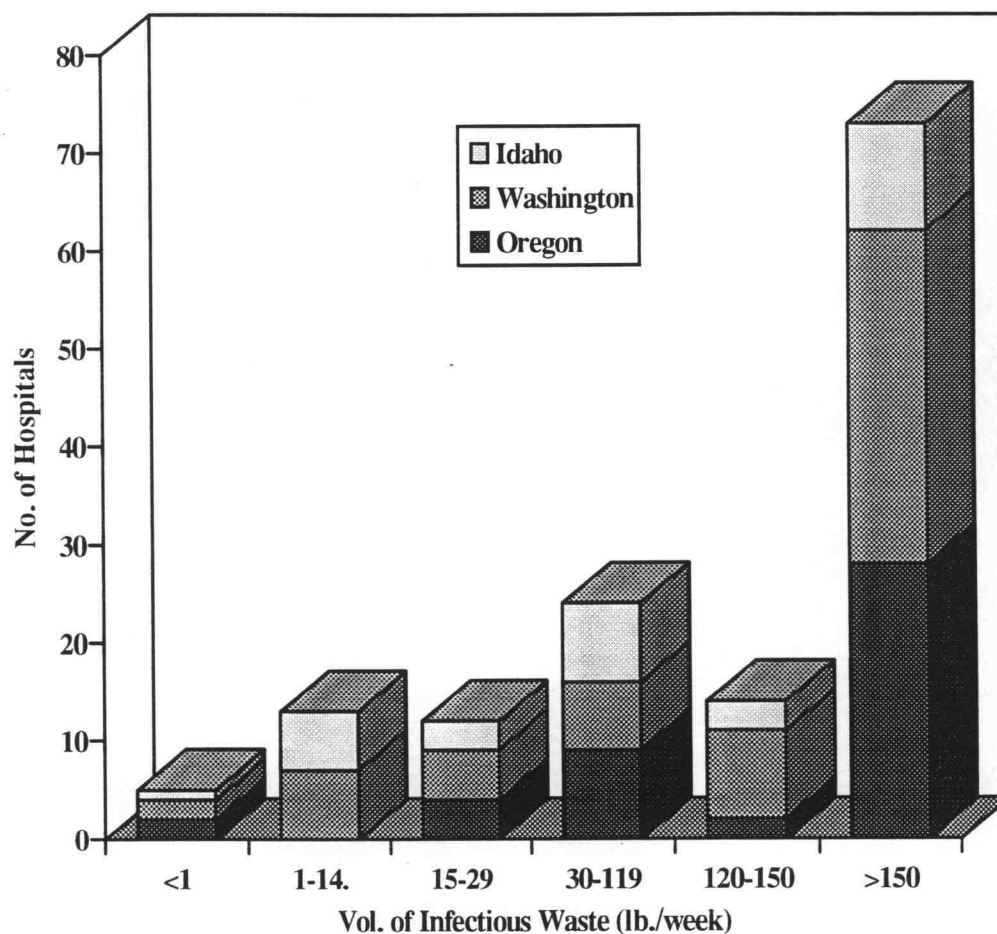
Volumes of Medical Waste Generated Weekly in OR, WA, and ID Hospitals.



The amount of medical and infectious waste in this study were not specific enough to estimate actual volumes of waste. As shown in Figure 2 and 3, the majority of hospitals in three states generated more than 400 pounds of medical waste and more than 150 pounds of infectious waste per week. Cross (1990) reported that a 250-bed hospital would generate 18-25 lb./bed/day of waste consisting 2-3 lb./bed/day of infectious waste, and did not average the amount of waste in pound per week.

Figure 3

Volumes of Infectious Waste Generated Weekly in OR, WA, and ID Hospitals.



The results from this study were not comparable with Cross's (1990) results for the following reasons. First, medical and infectious waste is not uniformly defined in hospitals. In this study, medical waste included certain types of hazardous waste and household waste produced in hospitals (see Appendix B). In Cross' (1990) study,

however, waste generated in hospitals also included food waste, bond paper, Green bar paper, card board, batteries, and aluminum (Cross, 1990).

Another factor that differed between this study and other studies is the occupancy rate of the hospitals, which is used to calculate average amounts of waste produces. The occupancy rates of hospitals in this study average 61.9 percent in OR, 65.6 percent in WA, and 61.1 percent in ID (AHA, 1992). Rutala, Oddette, and Samsa's (1989) results were based on a 68.9 percent occupancy rate, which would contribute to dissimilar results. Higher occupancy rates result generally in the generation of greater amounts of waste. Rutala, Oddette, and Samsa (1989) reported the median amount of waste generated in hospitals the US was 15.3 lb./patient/day. Fifteen percent of this hospital waste was infectious waste (2.9 lb./patient/day). Thus, for these reasons, it is difficult to compare the amounts of waste generated in hospitals in this study to those observed in previous studies.

### **Waste Handling in Hospitals**

Most hospitals had an special Advisory Committee who are responsible for the management of hospital waste which includes segregating, labeling, storing, and treating waste. Most hospitals had more than one committee dealing with waste. The results indicated that 94 hospitals (58.4 %) had Advisory Committees for medical waste management, and 61.5 percent of hospitals in these three states had committees for infectious waste management. About 33 percent of hospitals had at least one committee in charge of radioactive, chemotherapy, and/or chemical waste. The Chi square statistic between Advisory Committees in various states with regard to the types of medical waste they manage,  $\chi^2_{0.05} = 3.0$  with  $df = 6$ , indicated no differences.

Some hospitals also had a Safety Committee or a special committee to manage sharps. Six hospitals, one in OR, five in WA, had only one Advisory Committee responsible solely for infectious waste.

### ***Waste Segregation***

The results indicated that 89 hospitals (55.3%) reported segregating infectious waste from medical waste, although 11.8 percent of hospitals did not respond to this question. ID had the highest percentage of hospitals segregating waste (64.7 %), and the percentages for WA and OR, were 54.1 and 51 percent, respectively.

Two previous studies reported much higher percentages of hospitals segregating infectious waste from medical waste. A study of infectious waste management conducted by the Washington Department of Ecology reported that 85 percent of hospitals in WA segregated infectious waste from medical waste (Washington Department of Ecology, 1989). A survey of 955 hospitals in the US by Rutala et al. (1989) stated that 95.4 percent of hospitals segregated infectious waste. In this study, only 54.1 percent of hospitals in WA segregated infectious waste from other waste.

One reason to account for Washington's low rate is that Washington is the only state that does not adopt waste management requirements in its statutes (Washington Department of Ecology, 1993). Instead, the state regulation allow local health departments to decide whether or not they should adopt biomedical waste requirements. Several local health departments have established ordinances to this effect: Seattle-King County, Snohomish County, Spokane County, and Tacoma-Pierce County (N. Theiren, personal communication, January 11, 1994).

Hospitals in Oregon also had low rate of waste segregation, although state law requires healthcare facilities generating infectious waste to segregate this waste from other waste at the point of generation (ORS 459.386-459.405, 1991; OAR 333-18-070, 1991). According to the data from this study, 71.6 percent of hospitals in OR used private waste haulers to transport medical waste to off-site treatment facilities. Waste hauler companies usually offer additional services, such as waste segregating and repackaging to hospitals (Reinhardt & Gordon, 1991), which may cause the less concerning about waste segregation in hospitals.

The low rate of waste segregation reported by hospitals in these three states may be explained by the high proportion of non-responses to this question. Thirty-nine hospitals (24.2%) did not answer this question. Hospitals in Oregon had the highest non-response rate (30%). The percentages of non-respondents in Washington and Idaho were 22.9 and 17.7 percent, respectively.

One of the reasons that it is important to account for segregation rate is that segregating infectious waste from other may affect the cost of waste disposal in hospitals. As stated by Fay et al. (1990), segregation methods help hospitals eliminate the cost of special handling, treatment and disposal of infectious waste. In addition, waste segregation is one of the methods which is used to reduce the amount of waste with multiple hazards (mixed waste). This mixed waste usually presents special problems for waste management, treatment, and disposal because of the difficulty in finding methods that are compatible with all hazards (Reinhardt & Gordon, 1990).

### ***Labeling of Waste Containers***

One hundred forty-eight hospitals (91.9 %) replied that infectious waste containers were labeled (see Table 12). Approximately 60 percent of hospitals reported that

containers used to keep chemical and chemotherapy or antineoplastic waste were properly labeled. In spite of the dangers radioactive waste presents, only 55 percent of hospitals identified containers of radioactive waste. Infectious and radioactive waste are the only types of waste that are regulated by state and federal agencies (40 CFR part 259.44 & 10 CFR part 61.57). This result must be interpreted with caution, however, because 38 percent of the respondents indicated that the labeling of radioactive waste was not applicable in their facility. Results that include only those facilities in which radioactive waste was generated indicated that 88.7% of hospitals labeled this waste appropriately (see Figure 4).

Because of the limited disposal facilities, each state must be responsible for waste generated within its boundaries (PL. 99-240, 1989). In addition, most licensee hospitals that generate radioactive waste are encouraged to hold their waste a minimum of 10 half-lives before disposal to allow for radioactive decay (10 CFR part 35).

Even though chemical waste was generated by 81.4 percent of hospitals, containers of this waste were not marked properly nearly twice as often as containers of radioactive waste (see Figure 5). One explanation for this may be that all chemicals regularly used in hospitals do not necessarily require special treatment as hazardous waste. Rather most chemicals utilized in hospitals are disposed of by conventional methods such as domestic sewage systems (Reinhardt & Gordon, 1991). Another reason may be that chemical substances used in hospitals are often labeled as hazardous according to different standards set by the EPA (see Table 4) (Reinhardt & Gordon, 1991). For example, chemical waste packages and containment devices containing waste with the hazardous characteristics of ignitability, corrosivity, toxicity, and/or reactivity, must be labeled according to 40 CFR part 172.400.



Table 12

Labeled Containers of Waste in Hospitals.

Types of Waste	No. of Hospitals Labeling Waste Containers <sup>a</sup> (% of total hospitals in each state)			Total
	Oregon (53)	Washington(74)	Idaho (34)	
Chemical Waste	32 (60.4%)	52 (70.3%)	16 (47.1%)	100 (62.1%)
Radioactive Waste	35 (61.0%)	42 (56.8%)	12 (35.3%)	89 (55.3%)
Chemotherapy Waste	39 (73.6%)	42 (56.8%)	17 (50.0%)	98 (60.9%)
Infectious Waste	49 (92.5%)	69 (93.2%)	30 (88.2%)	148 (91.9%)

<sup>a</sup>In each hospital it was possible to label more than one type of waste container.

Figure 4

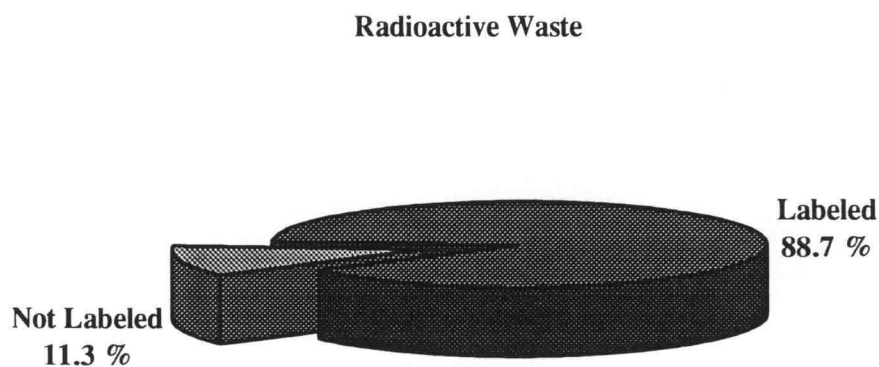
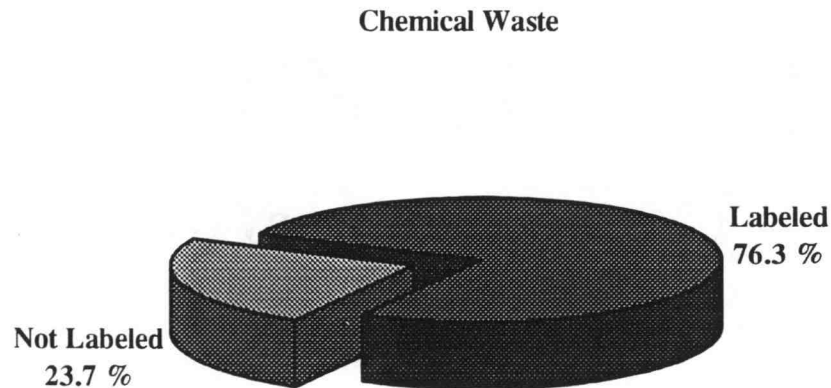
Percentage of Facilities That Generated and Labeled Radioactive Waste Containers.

Figure 5

Percentage of Facilities That Generated and Labeled Chemical Waste Containers.

Antineoplastic drugs used in chemotherapy treatments are regulated only as when they are unemptied, discarded source containers (40 CFR part 261.33). Thus, the majority of chemotherapy waste is not regulated by the EPA. However, nearly a third (31.7 %) of the hospitals did labeled containers of chemotherapy waste.

***Waste Storage***

As a result of the problems surrounding air pollution control concerns of the public, regulatory requirements, and high cost, many hospitals prefer to hire private companies to haul, treat, and dispose of their medical waste (Rubin, Buckner & Boyle, 1991). Thus, waste storage becomes a necessary part of waste handling practices. An average of 81.4 percent of hospitals in this study indicated that they had a special area for medical waste storage. Most hospitals (86.3%) responded that infectious waste was

stored in special areas. There were no differences between hospitals in three states and the types of waste that hospitals stored ( $\chi^2_{0.05} = 2.406$  with  $df = 6$ ) (see Table 13).

Table 13

Types of Waste Kept in Storage Areas of Hospitals in Each State.

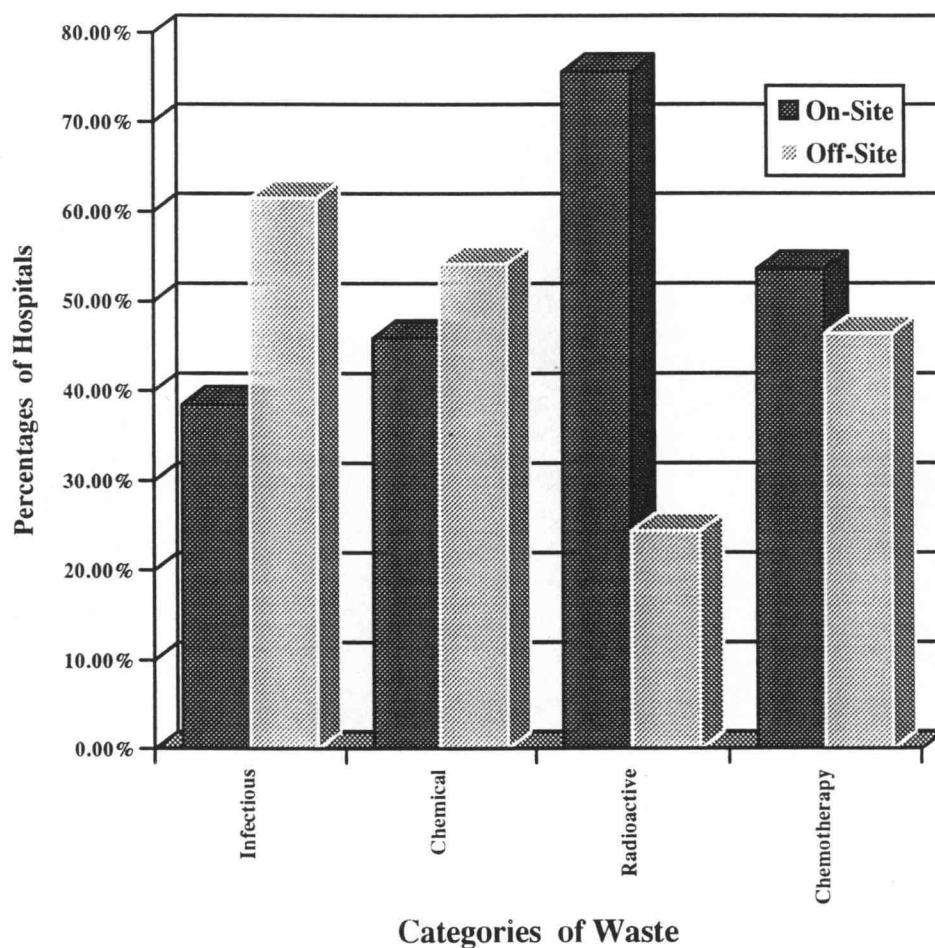
Types of Waste	No. of Hospitals Having Waste Storage Areas <sup>a</sup>			Total
	(% from a total of each state)			
	Oregon (53)	Washington(74)	Idaho (34)	
Chemical Waste	30 (56.6%)	44 (59.5%)	13 (38.2%)	87 (54.0%)
Radioactive Waste	30 (56.6%)	40 (54.1%)	9 (26.5%)	79 (49.1%)
Chemotherapy Waste	33 (62.3%)	39 (52.7%)	12 (35.3%)	84 (52.2%)
Infectious Waste	47 (88.7%)	67 (90.5%)	25 (73.5%)	139 (86.3%)

<sup>a</sup>In each hospital, it was possible to have storage areas for more than type of waste.

In hospitals which had storage areas for waste, chemical waste and regulated infectious waste were usually stored in an off-site area, for example, in another building. Radioactive waste and chemotherapy waste were more often kept in an on-site area, such as a main building (see Figure 6). This arrangement appears to be convenient for both generators (hospitals) and haulers, when large amount of waste is produced (Reinhardt & Gordon, 1990; US Department of Health and Human Services, 1990).

Response rates to questions about storage may reflect the differences in state regulations. For example, hospitals in Idaho may store their infectious waste in proper storage areas which afford protection from rain and wind, pose a low risk of exposure to the public, are posted with warning signs, and do not provide breeding places or food

Figure 6

Percentages of Hospitals That Stored Various Waste.

sources for insects and rodents. In addition, infectious waste may be stored for up to 90 days at temperatures less than 32° F. At higher temperature, it must not be stored more than seven days (Idaho Department of Health and Welfare, 1990). The requirement in Oregon is slightly different from that of Idaho. Hospitals in Oregon may keep pathological and biological waste up to seven days unless the waste is refrigerated at 33-45° F or less than 32° F for 30 days (OAR 333-18-070, 1991).

Storage of radioactive waste allows for the decay process of radionuclides. As mentioned in Chapter II, medical procedures commonly use radioactive substances which belong to class C, the lowest concentration and shortest half-life radionuclides (Hendee, 1993). In order to reduce the cost of disposal, radioactive waste is placed into safe containers and stored in safe areas until radioactivity approaches to the background levels. Allowing radioactive materials to be stored in this manner reduce the amount of radioactive material that must be transported to other sites for disposal (Hendee, 1993), and lessens the risk of exposure to radioisotopes.

### **Waste Treatment and Disposal Techniques**

Two groups of questions were used to collect data related to waste treatment and disposal techniques. The first group consisted of questions regarding sharps and chemotherapy waste. Question 4 asked how hospitals treated and disposed of sharps. Questions 7 and 7.1 were sequential, asking whether or not hospitals generated chemotherapy waste, and if so, and how they disposed of it. The second group were used to acquire information regarding incineration (questions 8 and 9), and other medical waste treatment techniques currently applied in hospitals (question 10).

#### ***Treatment Techniques for Sharps***

Incineration was the most frequently reported technique used in the treatment and disposal of sharps by hospitals in OR, WA, and ID (33.9%). The second most frequently reported treatment techniques was hiring disposal companies or contracted haulers for shipping to treatment facilities (19.3%). Sixteen hospitals (12.6 %) in OR and WA reported using a sophisticated technique for treatment of sharps, Electro-Thermal-

Deactivation™ (ETD™). Several other hospitals sent sharps to be incinerated to main hospitals in the nearby area. Autoclaving, mailing to other facilities and landfilling were other options used for sharps disposal.

Ninety-six hospitals (59.6%) in OR, WA, and ID stated that they disposed of sharps differently from other waste, and fifteen hospitals (7.9%) did not indicate whether or not they disposed of sharps differently from other waste. This finding is surprisingly low because sharps are categorized as an infectious waste category by the CDC and all three states in this study (US. Department of Health and Human Services, 1987; OAR 459.386,1991: RCW 70.95W, 1992 & Idaho Department of Health and Welfare, 1990).

Both incineration and steam sterilization are suitable treatment techniques for sharps (US. EPA, 1986). There are several advantages and disadvantages to these techniques. One advantage of incineration is that the high temperature in the combustion chamber effectively burn plastics and metal into ash which is disposed of in landfills. However, both plastic and metal are significant sources of air pollutants produced by incinerators (Chang, Glasm & Capt. Hickman, 1992; Hasselriis & Constantine, 1992). Steam sterilizers do not destroy the sharps. Steam-sterilized sharps are still intact and may cause physical injuries to treatment operators and/or waste handlers. Steam sterilization, however, does not release toxic by-products into the atmosphere.

Another option for the treatment of sharps is ETD™. Sharps are exposed to high temperatures generated by long radiowaves for periods of time long enough to kill infectious agents (R. Johnson, personal communication, January 20, 1994). The plastic contents are separated and sent to sharps companies for recycling. However, ETD™ is still a new technology, and further study into this technique is ongoing.

### *Treatment Techniques for Chemotherapy Waste*

Eighty-two of the 161 hospitals (50.9%) returning questionnaires regularly generated chemotherapy waste. The majority of these hospitals were in OR and WA, 19.9% and 23.6% percent, respectively. These hospitals mostly incinerated (43.2 %) and/or disposed of their chemotherapy waste as hazardous waste (44.1%) (see Figure 5). Other disposal methods reported by respondents were disposal private companies, return to vendors, and incineration at off-site facilities. Some hospitals adopted more than one method for chemotherapy waste disposal. For example, several hospitals indicated treating the chemotherapy waste as hazardous waste, and incineration.

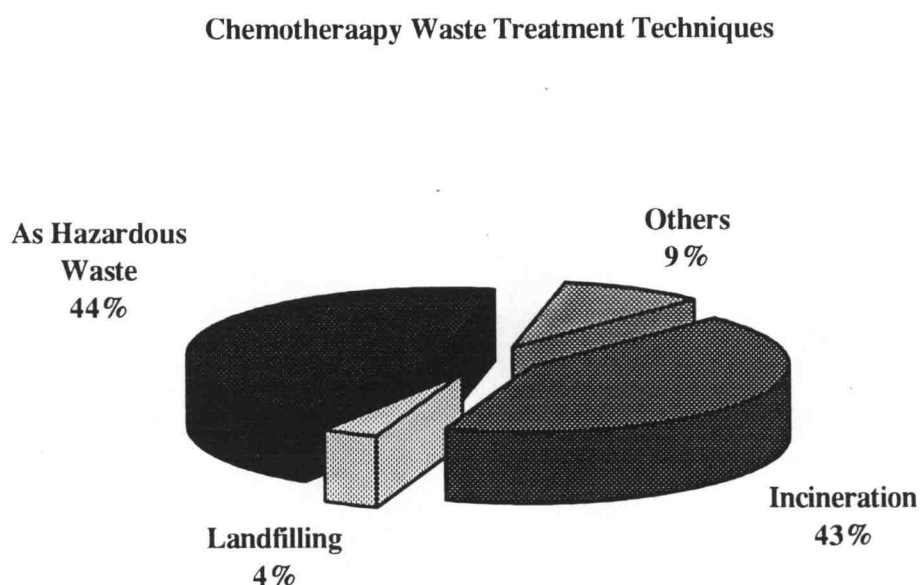
Even though the EPA listed seven kinds of antineoplastic drugs and cytotoxic agents used in chemotherapy as discarded commercial chemical products, these chemicals are carcinogenic and toxic to human and animals (40 CFR 261.33(f), 1992 & Vaccare et al., 1984). Because of its potential toxicity, large quantities of expired or unopened containers should be processed as hazardous waste which must be disposed of in an EPA- or state-licensed hazardous waste facilities only (Reinhardt & Gordon, 1991). More than 80 percent of the hospitals that reported generating chemotherapy waste in this study, either incinerate or dispose of this waste as hazardous waste. Hospitals in OR reported the same proportion of these two methods, whereas hospitals in WA preferred disposing of their chemotherapy waste as hazardous waste. On the other hand, most hospitals (83 %) in ID mostly incinerated chemotherapy waste.

According to Adankiewicz & Mella (1990), incineration is a practical treatment technique for chemotherapy waste since waste will be completely incinerated by the high temperature in the combustion chambers. Volatilized chemical compounds are trapped by many air emission control system. However, hospitals should be concerned that several air emission control systems (gravity setters, centrifugal separators and electrostatic

precipitator) are not efficient enough to capture volatilized chemical compounds (Adankiewicz & Mella, 1990).

Figure 7

Treatment Techniques for Chemotherapy Waste of Hospitals in Three States.



***Incineration***

Sixty-nine hospitals (45.7%) in OR, WA, and ID reported that they had stopped operating their incinerators. Forty-one hospitals (27.2%) never have had incinerators. In WA, the highest percentage of hospitals reported discontinuing use of their incinerators (60.3%) (see Table 14). Differences between hospitals in each state by the status of their incinerators (currently use, no longer use, and never have had) were found using the  $\chi^2$  test: ( $\chi^2_{0.05} = 20.8$ , with  $df = 4$ ;  $p < 0.005$ ).



Table 14

Status of Hospital Incinerators in OR, WA, and ID.

Status	Oregon	Washington	Idaho	Total
<b>Currently use</b>	11 (21.6%)	14 (20.6%)	16 (50%)	41 (27.2%)
<b>No longer use</b>	18 (35.3%)	41 (60.3%)	10 (31.2%)	69 (45.6%)
<b>Never have had</b>	22 (43.1%)	13 (19.1%)	6 (18.8%)	4 (27.2%)
<b>Total<sup>a</sup></b>	51 (100%)	68 (100%)	32 (100%)	151 (100%)

<sup>a</sup>Ten hospitals did not respond this question.

More hospitals in OR reported they "never have had" incinerators than expected. In ID, there were more hospitals still operating their incinerators than expected. Due to the smaller size of hospitals in ID ( mean number of beds = 89 beds) compared with those in OR (mean number of beds = 143 beds), it is possible that less waste is generated in ID hospitals allowing for more cost effective treatment of medical waste on-site. In addition, specific regulations regarding medical waste incinerators in ID are being developed. To date, although hospitals in ID must comply with government requirements, such as the Toxic Air Pollution Policy and National Ambient Air Standards, these are only general requirements, and usually applied only to general municipal solid waste incinerators (D. Pitman, personal communication, January 31, 1994). However, as stated by Pitman (1994), in the near future the number of hospital incinerators may decrease when states promulgate new medical waste incinerator requirements.

To date, hospital incinerators in OR, on the other hand, must meet the specific infectious waste and/or crematory incinerators requirements promulgated in 1990 by Oregon Department of Environmental Quality (OAR 340-25-850, 1990). According to these incinerator regulations, hospitals that operate or plan to operate both existing

incinerators constructed or modified prior to March 13, 1990, and new incinerators constructed or modified on or after March 13, 1990, must comply with several requirements. For example, hospitals were required to use Best Available Control Technology (BACT) to maintain the overall highest air quality levels. These regulations also limited many types of air emissions, such as particulate materials, hydrogen chloride, sulfur dioxide, carbon monoxide, nitrogen oxide and opacity. These regulations also limited types of incinerated waste; no radioactive and hazardous waste was allowed to be burned in infectious waste incinerators (OAR 340-25-865, 1990). These infectious waste and crematory incinerator regulations have impacted on all incinerators operated in hospitals, and the determining factor as to whether or not hospitals should incinerate medical waste on-site.

More hospitals in WA than expected reported that they stopped operating their incinerators. This may be because of the stringent state requirements. According to RCW 70.95.710, hospital incinerators must not produce any visible combustible materials in incineration ash (Washington Department of Ecology, 1993). Moreover, in several areas, local authorities have enacted biomedical waste incineration regulations which are stricter than the state's requirements. For example, the Puget Sound Air Pollution Control Agency, a local agency, requires the use of multiple chamber incinerators to burn biomedical waste (Washington Department of Ecology, 1993).

Most incinerators in WA state were installed during 1970s, and were usually found in hospitals located in heavily populated counties. Half of these incinerators had no emission control systems (Washington Department of Ecology, 1989). Therefore, hospitals were obliged to install expensive air emission control equipment to meet the local and state requirements. This might be one reason contributing to the shut down of incinerators in 60.3 percent of WA hospitals, and the hiring of contracted medical waste companies in their stead. Another reason is that there are possibly larger amounts of

medical waste generated by hospitals in WA because the higher occupancy rate than that of hospitals in OR and ID.

Hospitals which had stopped operating their incinerators, had done so within five years for the following reasons: the Air Pollution Control requirements (31.3 %), cost of the redesigning (26.2 %), the federal and state requirements (23.1 %), and expensive maintenance (15.9 %). Hospitals which were still operating their incinerators dispose of incineration ash in state sanitary landfills (88.9 %).

Green (1992) noted the current trend to add air pollution control systems, or to use regional incinerators that have installed such air pollution control systems. One reason for this trend is that the Clean Air Act Amendments of 1990, which regulates sources of toxic air emissions, hydrocarbon nitrogen dioxide, and volatilized organic chemicals (Dutta, 1990). Incineration of medical waste is a significant source of these pollutants. For example, the study in New York hospitals reported that 94 percent of items generated in patient care areas are plastics (Green, 1992). Therefore, many hospitals must install air pollution control system to their incinerators to meet federal and state air quality control requirements.

Hospital incinerators built in the last decade rarely meet the new federal and state air pollution control requirements (Fay et al., 1990). Air pollution control requirements can increase the price of a hospital incinerator to over one million dollars excluding operation and maintenance costs (Anonymous, 1991). In addition, the toxic residue from incinerators is another important consideration. Unlike bottom ash, most fly ash contains hazardous compounds which must be disposed of in EPA-permitted hazardous waste landfills, not in sanitary landfills (Reinhardt & Gordon, 1991).

Public perception is another problem associated with hospital incinerators because citizens often adopt a *not-in-my-back-yard* (NIMBY) attitude. This attitude makes it even more difficult for hospitals to install a new incinerators. Hospitals not only must meet state requirements, but also must participate in the public hearing process. Thus,

alternative medical waste treatment techniques are now being considered by many hospitals.

### ***Other Treatment Techniques***

Besides incineration, other techniques are used to treat medical and infectious waste in hospitals. The most frequently reported method was hiring private haulers that transport medical waste to treatment facilities or to landfills for disposal (61.5%). The next most frequently reported techniques were pouring into municipal sewage (46.6%) and autoclaving (32.3%). Other methods adopted by hospitals included ETD™ (macrowaving), hydropulping (chemical disinfectants), microwaving, and grinding before pouring into municipal sewage (see Table 15). The results indicated that hospitals in OR and WA applied microwave and ETD™ methods to their medical waste treatment options, while those in ID did not. In fact, most hospitals in ID either hired private medical waste haulers to transport waste to treatment facilities or to landfills, or autoclaved or poured waste into municipal sewage system. No hospitals reported using irradiation technique for medical waste treatment technique.

Hospitals continue to use other available medical waste treatment techniques to disinfect or dispose of some types of waste. According to US EPA (1986), Cross et al. (1990) and Reinhardt & Gordon (1991), several techniques are still suitable and reliable for medical waste. Despite low rates of waste reduction, steam sterilization is commonly used as either a back-up treatment, or as a pre-treatment technique prior to transportation to incineration facilities or disposal of in sanitary landfills. Pouring into the municipal sewage system is a convenient and inexpensive technique for liquid and semi-liquid waste disposal. Liquids and semi-liquids will be diluted by large quantities of sewage water before reaching waste water treatment facilities, which are required to provide secondary

treatment (US. EPA, 1986; OAR 459.386,1991 & Idaho Department of Health and Welfare, 1990).

Table 15

Comparison of Medical Waste Treatment Methods Used by Hospitals in Three States.

Treatment Methods	Hospitals in Three States (%) <sup>a</sup>			Total (%) <sup>c</sup>
	Oregon <sup>b</sup>	Washington <sup>b</sup>	Idaho <sup>b</sup>	
<b>Autoclaving</b>	15 (28.3 %)	24 (32.4 %)	13 (38.2 %)	52 (32.3%)
<b>Chemical Disinfecting or</b>				
<b>Hydropulping</b>	6 (11.3 %)	7 (9.5 %)	3 (8.8 %)	16 (9.9%)
<b>Microwaving</b>	4 (7.6 %)	5 (6.8 %)	0	9 (5.6%)
<b>Irradiation</b>	0	0	0	0
<b>Grind before Pour into</b>				
<b>Municipal-Sewage System</b>	3 (5.7 %)	2 (2.7 %)	1 (2.9 %)	6 (3.7%)
<b>Pour into Municipal Sewage</b>				
<b>System</b>	28 (52.8 %)	34 (46.0 %)	13 (38.2 %)	75 (46.6%)
<b>ETD™ (Macrowaving)</b>	9 (17.0 %)	13 (17.6 %)	0	22 (13.7%)
<b>Depositing in Landfills</b>	25 (47.7 %)	26 (35.1 %)	16 (47.7%)	67 (41.6%)
<b>Use of Private Medical</b>				
<b>Waste-Haulers</b>	38 (71.7 %)	46 (62.2 %)	15 (44.1 %)	99 (61.5%)

<sup>a</sup>percentages reflect proportion of hospitals using methods within each state

<sup>b</sup>each hospital can apply more than one treatment method.

<sup>c</sup>percentage of hospitals using methods based on all respondent hospitals (n=161)

Certain methods appears as on-site treatments while others were more apt to be performed at off-site locations. For example, conventional methods, such as autoclaving, using chemical disinfectants or hydropulping, and pouring into the municipal sewage system, were often performed on-site in hospitals. On the other hand, new treatment techniques used to treat medical waste were performed at off-site facilities. For example, all medical waste treated by microwave and ETD™ was shipped to off-site facilities (see Figure 8).

Two types of off-site treatment facilities: are available contracted waste management companies and regional facilities (Reinhardt & Gordon, 1991). A contracted waste management company option has become very popular with many hospitals. With this option, hospitals are usually concerned about segregating, packaging of waste, and wait for waste to be picked up for off-site treatment. Contracted waste companies then transport, store, treat and dispose of the waste. Although most off-site facilities use sophisticated and expensive technologies, hospitals benefit from the economies of scale that waste management companies can offer (Reinhardt & Gordon, 1991). However, hospitals are liable for the safety of the employees of contracted companies who perform work at hospitals. In addition, hospitals are liable for waste generated and the harm from waste when it is disposed of or treated improperly, so are apt to be very careful when selecting contracted companies (Reinhardt & Gordon, 1991).

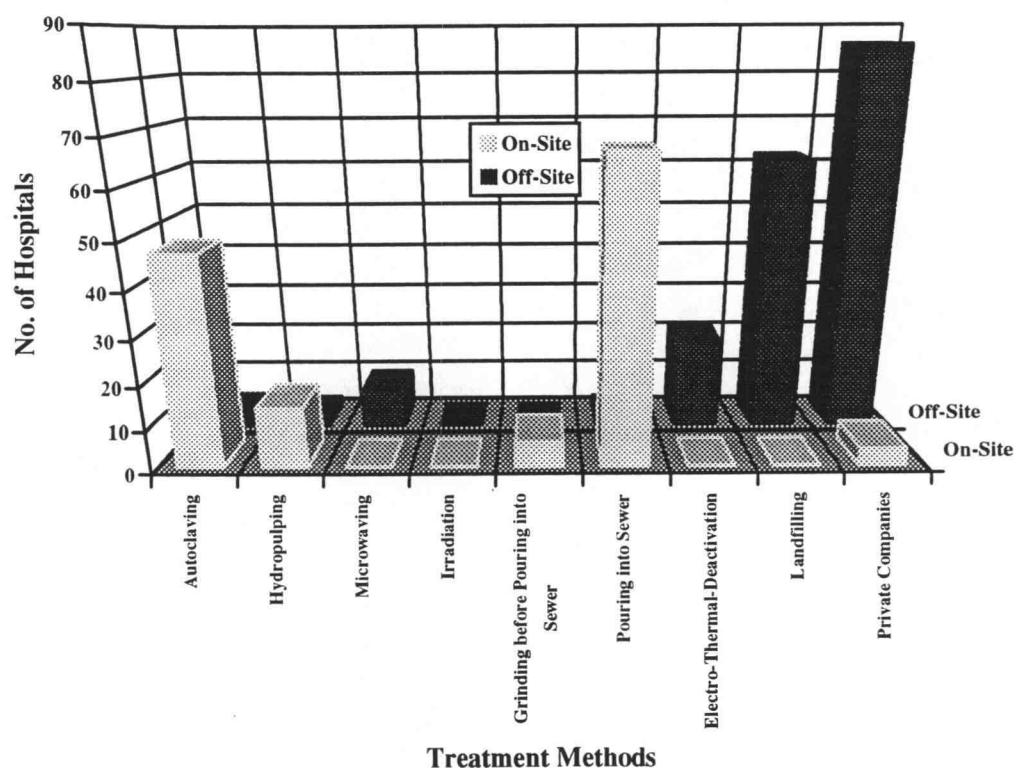
A regional facility is another type of off-site treatment option for hospitals. With this option, one hospital owns a medical waste treatment facility and accepts waste from other generators in the same area. Several hospitals in OR and ID commented in questionnaires that they sent medical waste to be incinerated at other hospitals. Because of the liabilities, this option is less popular, although this is a valuable community service provided for small hospitals.

Both ETD™ and microwaving are very new waste treatment technologies developed during the last five years. The ETD™ technique offers several advantages in

that plastics from treated sharps can be recycled by sharps companies and ETD™ is applicable for almost all types of medical waste. As claimed by the Stericycle Co., WA, the ETD™ technique produces no pollution whereas, the microwaving technique possibly produces volatile material. ETD™ is a copyrighted technology owned by Stericycle, and is available in limited areas (R. Johnson, personal communication, January 20, 1994; Spurgin, 1991). Microwaving has been successfully used in Europe and can be installed in existing hospitals (Spurgin, 1991).

Figure 8

Number of Hospitals Using Various Treatment Method.



## Chapter V

### CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

Numerous federal, state and other agencies are involved in medical waste management. These agencies establish regulations, guidelines and standards which define this waste, and also mandate waste handling practices, as well as waste treatment and disposal techniques. However, many discrepancies regarding medical waste management occur. For example, many terms were used to identify infectious waste in hospitals such as "regulated medical waste", "medical waste", "biological waste", "biohazardous waste", and "infectious waste". Even though state regulations were followed for medical waste management in hospitals, almost all hospitals also adopted medical and infectious waste definitions from other agencies such as the EPA, CDC, OSHA, JCAHO, AMA and APIC.

Hospitals tended to consider more types of medical waste to be infectious than is required by state regulatory definitions. Six types of medical waste were generally categorized as infectious waste by hospitals in OR, WA and ID: blood specimens and blood products, all sharps, microbiology laboratory waste, pathological waste, body parts and waste from surgery rooms. Moreover, more than half of hospitals inaccurately treated chemotherapy waste as infectious waste. On the other hand, several hospitals were in violation of state law by managing only contaminated sharps as infectious waste. These results implied that there was no widespread understanding of how medical and infectious waste should be defined. It is believed that the reason hospitals over-manage their infectious waste is due to safety and liability considerations.

An estimate of the interval volumes of medical and infectious waste generated in hospitals showed that the majority of hospitals in these three states generated waste in the



same range: more than 400 pounds of medical waste per week and more than 150 pound of infectious waste per week. These numbers, however, were not specific enough to estimate actual volumes of waste.

Most hospitals in this region have Advisory Committees responsible for planning medical waste management in their facilities. Despite the existence of these committees, only half of hospitals responding reported that they segregated infectious waste from other medical waste. These hospitals might prefer treating all medical waste as infectious waste because it is more convenient for staff to throw all waste into a common container. In addition, hospitals that insist on waste segregation practices must educate all the staff in hospitals, including physicians, nurses, technicians, and janitors, as well as providing proper containers. This is a considerable undertaking. Also, in certain circumstances in which time and quick decisions are critical, waste segregation practices are not suitable, such as in operation rooms, intensive care units, and emergency rooms.

The majority of hospitals labeled infectious waste containers and stored them in special areas separated from main buildings. Whereas most radioactive waste was stored off-site, chemotherapy waste and chemical waste were kept both on-site and off-site. This is because many types of chemotherapy and chemical waste can be disposed of by discharging these wastes into the sewage system. With the exception of the low proportion of waste segregation, medical waste generated by hospitals in this region was handled properly prior to treatment and disposal processes.

Sharps were categorized as one type of infectious waste that must be handled differently from other waste. However, only about 60 percent of the hospitals in this region did dispose of their sharps differently from other waste, which suggests that hospitals may need to pay particular attention to this concern. Incineration and transportation of sharps to off-site treatment facilities were the most frequently used treatment techniques. Other less frequently applied techniques that hospitals utilized for sharps treatment and disposal were autoclaving, mailing to other facilities and landfilling.

A new technique, ETD™, was reported by hospitals in OR and WA as another sharps treatment technique.

Only half of hospitals in this region reported that they regularly generated chemotherapy waste. In general, chemotherapy waste were inappropriately managed by hospitals in this region. Most hospitals improperly designated chemotherapy waste to be infectious, and disposed of this waste as hazardous waste, even though chemotherapy waste is usually defined as neither infectious nor hazardous waste by the EPA.

Hospitals in OR and WA reported that they either never operated incinerators or that they no longer operated their incinerators due to increased regulations regarding air pollution emissions. However, hospitals in ID are currently using incinerators in the absence of state regulations limiting air pollution emissions from these types of facilities.

Hospitals in all three states reported that they preferred hiring private haulers to other medical waste treatment techniques. Frequently used on-site medical waste treatment techniques were the traditional techniques of autoclaving (steam sterilization) and pouring into the municipal sewage system. Two new technologies, microwaving and ETD™, have also been introduced as an alternative off-site treatment technique, even though there is very little research to document the environmental impact and efficiency of these new methods.

## **Recommendations**

The following recommendations are made based on the results of this study:

- Federal or state agencies should draft universal definitions of medical and infectious waste, which are suitable and specific enough so that both hospitals and accreditation organizations will be able to adopt them. With these commonly used

definitions, problems regarding over- and under-management of medical waste in hospitals will be possibly eliminated.

- States and hospitals should work together to help hospitals decrease the costs associated with medical waste management. States might adopt the formation of regional waste treatment facilities, which would aid hospitals in rural areas in adopting environmentally and economically sound medical waste treatment and disposal techniques. Hospitals using regional facilities are apt to pay less for waste transportation. Meanwhile, hospitals should monitor their medical waste segregation practices to encourage the separation of infectious waste from other less regulated medical waste, because these practices might help hospitals reduce their waste management costs.

- Waste management hierarchy programs (reduce, reuse, recycle) should be instituted in all hospitals. For example, administrators may promote recycling and the use of substitute materials or chemicals in their facilities. Also, whenever possible and feasible, hospitals should decrease the amount of disposable items and plastics to reduce the volatile organic compounds produced by incinerators. However, these waste management strategies must balance the need to conserve resources with the need to protect against communicable disease transmission.

- Hospitals should monitor their sharps management and disposal more intensively because many hospitals in this region disposed of sharps with other waste and some hospitals categorized only contaminated sharps as infectious waste. Unless treated by incineration, sharps must be carefully handled and disposed of due to the potential for causing needle-stick injuries.

- Hospitals should provide for continuous educational programs regarding medical and infectious waste handling practices to all personnel whose work involves waste handling. It is suggested that hospitals keep records of medical and infectious waste generated including volume of waste, occupational injuries and exposure to infectious agents, so that these parameters may be evaluated on an annual basis.

Several recommendations for further study include:

- A similar study might be conducted in other types of healthcare facilities, such as long term care facilities, dentist and physician offices, which also produce large volumes of medical and infectious waste.
- It is recommended that comparisons of medical waste management and treatment techniques used in different types of hospitals and in other geographic regions of the US. be conducted. These comparisons should be made between profit and non-profit hospitals, university and regular hospitals, and hospitals in the Pacific Northwest and other areas, because of economic differences and the types of waste these facilities manage.
- More studies regarding radioactive and chemotherapy waste handling and disposal techniques in hospitals are strongly recommended because of the particular risks that they pose.
- Finally, it is recommended that the environmental impact and efficiency of new techniques such as ETD™ be assessed.

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## **APPENDICES**

**Appendix A**  
**Hospitals in Oregon, Washington and Idaho**  
**Listed in *the 1992 AHA Guide for Healthcare Field***

## Oregon

Albany General Hospital, 1046 W. Sixth Ave. Albany  
Oregon 97321 Tel. 503-926-2244

Ashland Community Hospital, 280 Maple St., Ashland (P.O. Box 98)  
Oregon 97520 Tel. 503-482-2441

Columbia Memorial Hospital, 2111 Exchange St., Astoria  
Oregon 97103 Tel. 503-325-4321

St. Elizabeth Hospital and Health Care Center, 3325 Pocahontas Rd., Baker City  
Oregon 97814 Tel. 503-523-6461

Southern Coos General Hospital, 640 W. Fourth, Bendon  
Oregon 97411 Tel. 503-347-2426

St. Charles Medical Center, 2500 N.E. Neff Rd., Bend  
Oregon 97701 Tel. 503-382-4321

Harney District Hospital, 557 W. Washington St., Burns  
Oregon 97720 Tel. 503-573-7281

Kaiser Foundation Hospital, 10200 S.E. Sunnyside Rd., Clackamas  
Oregon 97015 Tel. 503-652-2880

Bay Area Hospital, 1775 Thompson Rd., Coos Bay  
Oregon 97420 Tel. 503-269-8173

Coquille Valley Hospital, 940 E. Fifth St., Coquille  
Oregon 97423 Tel. 503-396-3101

Cottage Grove Hospital, 1340 Birch Ave., Cottage Grove  
Oregon 97424 Tel. 503-942-0511

Valley Community Hospital, 550 S.E. Clay St. Dallas (P.O. Box 378)  
Oregon 97338 Tel. 503-623-8301

Wallowa Memorial Hospital, 401 E. First St., Enterprise (P.O. Box 460)  
Oregon 97828 Tel. 503-426-3111

Sacred Heart General Hospital, 1255 Hilyard St., Eugene (P.O. Box 10905)  
Oregon 97440 Tel. 503-686-7300

Serenity Lane, 616 E. 16th., Eugene  
Oregon 97401 Tel. 503-687-1110

Peace Harbor Hospital, 400 Ninth St., Florence (P.O. Box 580)  
Oregon 97439 Tel. 503-997-8412

Tuality Forest Grove Hospital, 1809 Maple St., Forest Grove  
Oregon 97116 Tel. 503-357-2173



## Oregon

Curry General Hospital, 220 E. Fourth St. , Gold Beach  
Oregon 97444 Tel. 503-247-6621

Joseph Memorial Hospital, 715 N.W. Dimmick St., Grant Pass  
Oregon 97526 Tel. 503-476-6831

Southern Oregon Medical Center, 1505 N.W. Washington Blvd, Grant Pass  
Oregon 97526 Tel. 503-479-7531

Mount Hood Medical Center, 24800 S.E. Stark, Gresham  
Oregon 97030 Tel. 503-667-1122

Pioneer Memorial Hospital, 564 E. Pioneer Dr., Heppner(P.O. Box 9)  
Oregon 97836 Tel. 503-676-9133

Good Shepherd Community Hospital, 610 N.W. 11th. St., Hermiston.  
Oregon 97838 Tel. 503-567-6483

Tuality Community Hospital, 335 S.E. Eighth, Hillsboro (P.O. Box 309)  
Oregon 97123 Tel. 503-681-1111

Hood River Memorial Hospital, 13th. and May Sts., Hood River (P.O. Box 149)  
Oregon 97031 Tel. 503-386-3911

Blue Mountain Hospital, 170 Ford Rd., John Day  
Oregon 97845 Tel. 503-575-1311

Merle West Medical Center, 2865 Daggett St., Klamath Falls  
Oregon 97601 Tel. 503-882-6311

Grande Ronde Hospital, 900 Sunset Dr., Lagrande (P.O.Box 3290)  
Oregon 97850 Tel. 503-963-8421

Lake District Hospital, 700 S.J St., Lakeview  
Oregon 97630 Tel. 503-947-2114

Lebanon Community Hospital, 525 N. Santiam Hwy., Lebanon (P.O. Box 739)  
Oregon 97355 Tel. 503-258-2101

North Lincoln Hospital, 3043 N.E. 28th. St., Lincoln City (P.O. Box 767)  
Oregon 97367 Tel. 503-994-3661

Mountain View Hospital District, 1270 A St., Madras  
Oregon 97741 Tel. 503-475-3882

McMinnville Community Hospital, 603 Baker St., McMinnville  
Oregon 97128 Tel. 503-472-6131

Providence Hospital, 1111 Crater Lake Ave., Medford  
Oregon 97504 Tel. 503-773-6611

## Oregon

Rogue Valley Medical Center, 2825 Barnett Rd., Medford  
Oregon 97504 Tel. 503-773-6281

Providence Milwaukie Hospital, 10150 S.E. 32nd Ave., Milwaukie  
Oregon 97222 Tel. 503-652-8300

Newberg Community Hospital, 5901 Villa Rd., Newberg  
Oregon 97132 Tel. 503-538-1372

Pacific Community Hospital, 930 S.W. Abbey St., Newport  
Oregon 97365 Tel. 503-265-2244

Malheur Memorial Hospital District, 1109 Park Ave., Nyssa  
Oregon 97913 Tel. 503-372-2211

Holy Rosary Medical Center, 351 S.W. Ninth St., Ontario  
Oregon 97914 Tel. 503-889-5331

Willamette Falls Hospital, 1500 Division St., Oregon City  
Oregon 97045 Tel. 503-656-1631

Eastern Oregon Psychiatric Center, 2575 Westgate, Pendleton  
Oregon 97801 Tel. 503-276-4511

St. Anthony Hospital, 1601 S.E. Court Ave., Pendleton  
Oregon 97801 Tel. 503-276-5121

Bess Kaiser Medical Center, 5055 N. Greeley Ave., Portland  
Oregon 97217 Tel. 503-285-9321

Eastmoreland Hospital, 2900 S.E. Steele St., Portland  
Oregon 97202 Tel. 503-234-0411

Emanuel Hospital And Health Center, 2801 N. Gantenbein Ave., Portland  
Oregon 97227 Tel. 503-280-3200

Good Samaritan Hospital and Medical Center, 1015 N.W. 22nd Ave., Portland  
(P.O. Box 5624), Oregon 97210 Tel. 503-229-7711

Pacific Gateway Hospital, 1345 S.E. Harney, Portland  
Oregon 97202 Tel. 503-234-5353

Portland Adventist Medical Center, 10123 S.E. Market, Portland  
Oregon 97216 Tel. 503-257-2500

Providence Medical Center, 4805 N.E. Glisan St., Portland  
Oregon 97213 Tel. 503-230-1111

Shriners Hospitals for Crippled Children, Portland Unit, 3101 S.W. Sam Jackson Park Rd.,  
Portland, Oregon 97201 Tel. 503-241-5090

## Oregon

St. Vincent Hospital and Medical Center, 9205 S.W. Barnes Rd., Portland  
Oregon 97225 Tel. 503-297-4411

University Hospital (L.457), 3181 S.W. Sam Jackson Park Rd., Portland  
Oregon 97201 Tel. 503-494-8311

Veterans Affairs Medical Center (111F Infectious Diseases), 3710 U.S. Veterans Hospital Rd.,  
Portland (P.O. Box 1034) Oregon 97201 Tel. 503-220-8262

Woodland Park Hospital, 10300 N.E. Hancock, Portland  
Oregon 97220 Tel. 503-257-5500

Pioneer Memorial Hospital, 1201 N. Elm St., Prineville  
Oregon 97754 Tel. 503-447-6254

Central Oregon District Hospital, 1253 N. Canal Blvd., Redmond  
Oregon 97756 Tel. 503-548-8131

Lower Umpquo Hospital District, 600 Ranch Rd., Reedsport  
Oregon 97467 Tel. 503-271-2171

Douglas Community Hospital, 738 W. Harvard Blvd., Roseburg  
Oregon 97470 Tel. 503-673-6641

Mercy Medical Center, 2700 Stewart Pkwy., Roseburg  
Oregon 97470 Tel. 503-673-0611

Veterans Affairs Medical Center, 913 N.W. Garden Valley Blvd., Roseburg  
Oregon 97470 Tel. 503-440-1000

Oregon State Hospital, 2600 Center St. N.E., Salem  
Oregon 97310 Tel. 503-378-2348

Providence Seaside Hospital, 725 S. Wahanna Rd., Seaside (P.O. Box 740)  
Oregon 97138 Tel. 503-738-8463

Silverton Hospital, 342 Faireview St., Silverton  
Oregon 97381 Tel. 503-873-6336

Mc Kenzie-Willamette Hospital, 1460 G. St., Springfield  
Oregon 97477 Tel. 503-726-4400

Santiam Memorial Hospital, 1401 N. Tenth Ave., Stayton  
Oregon 97383 Tel. 503-769-2175

Mid-Columbia Medical Center, 1700 E. 19th St., The Dalles  
Oregon 97058 Tel. 503-296-1111

Tillamook County General Hospital, 1000 Third St., Tillamook  
Oregon 97141 Tel. 503-842-4444

## Oregon

Meridian Park Hospital, 19300 S.W. 65th Ave., Tualatin  
Oregon 97062 Tel. 503-692-1212

Dammasch State Hospital, 28801 S.W. 110th St., Wilsonville (P.O. Box 38)  
Oregon 97070 Tel. 503-682-3111

## Washington

Grays Harbor Community Hospital, 915 Anderson Dr., Aberdeen  
Washington 98520 Tel. 206-532-8330

Island Hospital, 1211 24th St., Anacortes  
Washington 98221 Tel. 206-293-3181

Snohomish County Public-Hospital Distric 3, Cascade Valley Hospital, 330 S. Stillaguamish St.,  
Washington 98223 Tel. 206-435-2133

Auburn General Hospital, 20 Second St. N.E., Auburn  
Washington 98002 Tel. 206-833-7711

Overlake Hospital Medical Center, 1035 116th Ave. N.E., Bellevue  
Washington 98004 Tel. 206-454-4011

St. Joseph Hospital, 2901 Squalicum Pkwy., Bellingham  
Washington 98225 Tel. 206-734-5400

Harrison Memorial Hospital, 2520 Cherry Ave., Bremerton  
Washington 98310 Tel. 206-377-3911

Naval Hospital, Boone Rd., Bremerton  
Washington 98312 Tel. 206-479-6600

Okanogan-Douglas County Hospital, 703 N.W. Second, Brewster (P.O. Box 577)  
Washington 98812 Tel. 509-689-2517

Providence Hospital-Centralia-Chehalis, 1820 Cooks Hill Rd., Centralia  
Washington 98513 Tel. 206-736-2803

Providence Hospital-Centralia-Chehalis, 500 S.E. Washington Ave. Chehalis  
(P.O. Box 1507), Washington 98532 Tel. 206-748-4444

Lake Chelan Community Hospital, 503 E. Highland Ave., Chelan (P.O.Box 908)  
Washington 98816 Tel. 509-682-2531

St. Joseph's Hospital, 500 E. Webster St., Chewelah (P.O. Box 197)  
Washington 99109 Tel. 509-935-8211

Tri-State Memorial Hospital, 1221 Highland Ave., Clarkston (P.O. Box 189)  
Washington 99403 Tel. 509-758-5511

Whitman Hospital and Medical Center, 1200 Almota Rd., Colfax  
Washington 99111 Tel. 509-397-3435

Mount Carmel Hospital, 982 E. Columbia St., Colville (P.O.Box 351)  
Washington 99114 Tel. 509-684-2561

Whidbey General Hospital, 101 N. Main St., Coupeville (P.O. Box 400)  
Washington 98239 Tel. 206-678-5151

## Washington

Lincoln County Hospital District 3, 10 Nichols St., Davenport (P.O.Box 68)  
Washington 99122 Tel. 509-725-7101

Dayton General Hospital, 1012 S. 3 rd.St., Dayton  
Washington 99328 Tel. 509-382-2531

Stevens Memorial Hospital, 21601 76th Ave. W., Edmond  
Washington 98206 Tel. 206-744-4000

Kittitas Valley Community Hospital, 603 S. Chestnut St., Ellensburg  
Washington 98926 Tel. 509-962-9841

Community Memorial Hospital, 2125 C St., Enumclaw (P.O.Box 218)  
Washington 98022 Tel. 206-825-2505

Columbia Basin Hospital, 200 S.E. Blvd., Ephrata  
Washington 98823 Tel. 509-754-4631

General Hospital Medical Center, 14th & Colby Ave., Everett (P.O.Box 1147 zip 98206)  
Washington 98201 Tel. 206-258-6300

Providence Hospital, Pacific and Nassau Sts, Everett (P.O. Box 1067 zip 98206)  
Washington 98201 Tel. 206-258-7123

U.S. Air Force Hospital, Fairchild Air Base  
Washington 99011 Tel. 509-247-5216

St. Francis Community Hospital, 34515, 9th Ave. S., Federal Way  
Washington 98003 Tel. 206-838-9700

Klickitat Valley Hospital, 301 S. Roosevelt, Goldendale (P.O. Box 5)  
Washington 98620 Tel. 509-773-4022

Coulee Community Hospital, 411 Fortuyn Rd. Grand Coulee (P.O. Box H)  
Washington 99133 Tel. 509-633-1753

Ocean Beach Hospital, Ilwaco  
Washington 98624 Tel. 206-642-3181

Kennewick General Hospital, 900 S. Auburn St., Kennewick (P.O. Box 6128)  
Washington 99336 Tel. 509-5865-5826

Careunit Hospital of Kirkland, 10322 N.E. 132nd, Kirkland  
Washington 98034 Tel. 206-821-1122

CPC Fairfax Hospital, 10200 N.E. 132nd St. Kirkland  
Washington 98034 Tel. 206-821-2000

Evergreen Hospital Medical Center, 12040 N.E. 128th St., Kirkland  
Washington 98034 Tel. 206-821-1111

## Washington

Cascade Oaks, 4800 College St., Lacey  
Washington 98503 Tel. 206-459-8811

St. John's Medical Center, 1614 E. Kessler Blvd., Longview (P.O. Box 3002)  
Washington 98632 Tel. 206-423-1530

Mark Reed Hospital, 322 S. Birch St., McCleary (P.O. Box 28)  
Washington 98557 Tel. 206-495-3244

Eastern State Hospital, P.O. Box A, Medical Lake  
Washington 99022 Tel. 509-299-4351

Valley General Hospital, 14701 179th S.E., Monroe (P.O. Box 646)  
Washington 98272 Tel. 206-794-7497

Morton General Hospital, 521 Adams St., Morton (Drawer C)  
Washington 98356 Tel. 206-496-5112

Samaritan Hospital, 801 E. Wheeler Rd., Moses Lake  
Washington 98837 Tel. 509-765-5606

Skagit Valley Hospital and Health Center, 1415 Kincaid St., Mount Vernon  
(P.O. Box 1376), Washington 98273 Tel. 206-424-4111

United General Hospital, 1971 Hwy. 20, Sedro Woolley, Mount Vernon  
(P.O. Box 410), Washington 98284 Tel. 206-856-6021

Newport Community Hospital, 714 W. Pine Sts., Newport (P.O. Box 669)  
Washington 99156 Tel. 509-447-2441

Naval Hospital(z Security), Oak Harbor  
Washington 98278 Tel. 206-257-9500

Odessa Memorial Hospital, 502 E. Amende Dr., Odessa (P.O. Box 368)  
Washington 99159 Tel. 509-982-2611

Capital Medical Center, 3900 Capital Mall Dr. S.W., Olympia  
Washington 98502 Tel. 206-754-5858

St. Peter Hospital, 413 Lilly Rd. N.E., Olympia  
Washington 98506 Tel. 206-491-9480

Mid-Valley Hospital, 810 Valley Way, Omak (P.O. Box 793)  
Washington 98841 Tel. 509-826-1760

Othello Community Hospital, 315 N. 14th St., Othello  
Washington 99344 Tel. 509-488-2636

Our Lady of Lourdes Health Center, 520 N. Fourth St., Pasco  
Washington 99301 Tel. 509-547-7704

## Washington

Garfield County Hospital District, 66 N. Sixth St., Pomeroy (P.O. Box 880)  
Washington 99347 Tel. 509-843-1591

Olympic Memorial Hospital, 939 Caroline St., Port Angeles  
Washington 98362 Tel. 206-457-8513

Jefferson General Hospital, 834 Sheridan, Port Townsend  
Washington 98368 Tel. 206-385-2200

Prosser Memorial Hospital, 723 Memorial St., Prosser  
Washington 99350 Tel. 509-786-2222

Pullman Memorial Hospital, N.E. 1125 Washington Ave., Pullman  
Washington 99163 Tel. 509-332-2541

Good Samaritan Community Healthcare, 407 14th Ave. S.E., Puyallup  
(P.O. Box 1247), Washington 98372 Tel. 206-848-6661

Quincy Valley Hospital, 908 Tenth Ave. S.W., Quincy  
Washington 98848 Tel. 509-787-3531

Group Health Eastside Hospital, 2700, 152nd Ave. N.E., Redmond  
Washington 98052 Tel. 206-883-5151

Valley Medical Center, 400 S. 43rd St., Renton  
Washington 98055 Tel. 206-228-3450

Ferry County Memorial Hospital, 470 N. Klondike Rd., Republic (P.O. Box 365)  
Washington 99166 Tel. 509-775-3998

Kadlec Medical Center, 888 Swift Blvd., Richland  
Washington 99352 Tel. 509-946-4611

East Adams Rural Hospital, 903 S. Adams St. Ritzville  
Washington 99169 Tel. 509-659-1200

Ballard Community Hospital, N.W. Market & Barnes, Seattle (P.O. Box C-70707)  
Washington 98107 Tel. 206-782-2700

Children's Hospital and Medical Center, 4800 Sand Point Way N.E., Seattle  
(P.O. Box C-5371), Washington 98105 Tel. 206-526-2000

Fifth Avenue Hospital, 10560 Fifth Ave. N.E., Seattle  
Washington 98125 Tel. 206-364-2050

Group Health Cooperative Central Hospital, 201 16th Ave. E., Seattle  
Washington 98112 Tel. 206-326-3000

Harborview Medical Center (ZA 38), 325 9th. Ave., Seattle  
Washington 98104 Tel. 206-223-3000



## Washington

Highline Community Hospital, 16251 Sylvaster Rd. S.W., Seattle  
Washington 98166 Tel. 206-244-9970

Northwest Hospital, 1550 N. 115th St., Seattle  
Washington 98133 Tel. 206-368-1700

Providence Medical Center, 500 17th Ave., Seattle  
(P.O. Box C-34008), Washington 98122 Tel. 206-320-2000

Schick Shadel Hospital, 12101 Ambaum Blvd. S.W., Seattle (P.O. Box 48149)  
Washington 98146 Tel. 206-244-8100

Swedish Hospital Medical Center, 747 Summit Ave., Seattle  
Washington 98104 Tel. 206-386-6000

University of Washington Medical Center, 1959 N.E. Pacific, Rc-35, Seattle  
Washington 98195 Tel. 206-548-3300

Veterans Affairs Medical Center, 1660 S. Columbian Way, Seattle  
Washington 98108 Tel. 206-762-1010

Virginia Mason Medical Center, 925 Seneca St., Seattle (P.O. Box 1930)  
Washington 98111 Tel. 206-624-1144

Mason General Hospital, 2100 Sherwood Lane, Shelton (P.O.Box 1158)  
Washington 98584 Tel. 206-426-1611

Willapa Harbor Hospital, Alder and Cedar Sts., South Bend (P.O.Box 438)  
Washington 98586 Tel. 206-875-5526

Deaconess Medical Center-Spokane, 800 W. 5 th. Ave., Spokane (P.O.Box 248 )  
Washington 99204 Tel. 509-458-5800

Holy Family Hospital, N. 5633 Lidgerwood St., Spokane  
Washington 99207 Tel. 509-482-0111

Mountainview Hospital of Spokane, 628 S. Cowley, Spokane (P.O.Box 598 zip 99210)  
Washington 99202 Tel. 509-624-3226

Sacred Heart Medical Center, W. 101 8th. Ave., Spokane  
Washington 99220 Tel. 509-455-3131

Shriner Hospitals for Crippled Children, Spokane Unit, 911 W. 5th. Ave., Spokane  
(P.O. Box 2472), Washington 99204 Tel. 509-455-7844

St. Luke's Memorial Hospital, S. 711 Cowley, Spokane (P.O.Box 2472 zip 99210)  
Washington 99202 Tel. 509-838-4771

Valley Hospital and Medical Center, E. 12606 Mission Ave., Spokane  
Washington 99216 Tel. 509-924-6650

## Washington

Veterans Affairs Medical Center, N. 4815 Assembly St. , Spokane  
Washington 99205 Tel. 509-328-4521

Sunnyside Community Hospital, 10th. and Tacoma Ave., Sunnyside (P.O. Box 719)  
Washington 98944 Tel. 509-837-1400

Allenmore Hospital, S. 19th and Union Sts., Tacoma (P.O. Box 11414 zip 98411)  
Washington 98405 Tel. 206-572-2323

Group Health Cooperative Inpatient Center, 315 S. K St., Tacoma, Mail Stop AB-ES  
(P.O. Box 5299), Washington 98415-0299 Tel. 206-594-1337

Mary Bridge Children's Hospital and Health Center, 317 S. K St., Tacoma  
(P.O. Box 5299), Washington 98405 Tel. 206-594-1400

Puget Sound Hospital, 215 S. 36th St., Tacoma (P.O.Box 11412 zip 98411)  
Washington 98408 Tel. 206-474-0561

Saint Clare Hospital, 11315 Bridgeport Way S.W., Tacoma (P.O. Box 99998)  
Washington 98499 Tel. 206-588-1711

St. Joseph Hospital and Health Care Center, 1718 S.I St., Tacoma (P.O.Box 2197)  
Washington 98405 Tel. 206-627-4101

Tacoma General Hospital, 315 S. K St.,Tacoma (P.O.Box 5299)  
Washington 98405 Tel. 206-594-1000

American Lake Veterans Affairs Medical Center, Tacoma  
Washington 98493 Tel. 206-582-8440

North Valley Hospital, Second & Western, Tonasket (P.O.Box 488)  
Washington 98855 Tel. 509-486-2151

Providence Hospital-Toppenish, 502 W. 4th. St., Toppenish (P.O. Box 672)  
Washington 98948 Tel. 509-865-3105

Southwest Washington Medical Center, P.O.Box 1600, Vancouver  
Washington 98668 Tel. 206-256-2000

St. Mary Medical Center, 401 W. Poplar St. (P.O.Box 1477), Walla Walla  
Washington 99362 Tel. 509-525-3320

State Penitentiary Hospital, P.O. Box 520, Walla Walla  
Washington 99362 Tel. 509-525-3610

Veteran Affairs Medical Center, 77 Wainwright Dr., Walla Walla  
Washington 99362 Tel. 509-525-5200

Walla Walla General Hospital, 1025 S. 2nd. Ave.(P.O. Box 1398), Walla Walla  
Washington 99362 Tel. 509-525-0480

## Washington

Central Washington Hospital, 1300 Fuller St. (P.O. Box 1887 zip 98807), Wenatchee  
Washington 98801 Tel. 509-662-1511

Skyline Hospital P.O. Box 99, White Salmon  
Washington 98672 Tel. 509-493-1101

Community Hospital, 3003 Tieton Dr., Yakima  
Washington 98902 Tel. 509-453-6561

St. Elizabeth Medical Center, 110 S. 9th. Ave., Yakima  
Washington 98902 Tel. 509-575-5000

Yakima Valley Memorial Hospital, 2811 Tieton Dr., Yakima  
Washington 98902 Tel. 509-575-8000

## Idaho

Harms Memorial Hospital District, 510 Roosevelt, American Falls (P.O.Box 420)  
Idaho 83211 Tel. 208-226-2327

Lost Rivers District Hospital, 551 Highland Dr., Arco (P.O.Box 145)  
Idaho 83213 Tel. 208-527-8206

Bingham Memorial Hospital, 98 Poplar St., Blackfoot  
Idaho 83221 Tel. 208-785-4100

State Hospital South, E. Alice St., Blackfoot (P.O. Box 400)  
Idaho Tel. 208-785-1200

Idaho Elks Rehabilitation Hospital, 204 Fort Pl., Boise (P.O. Box 1100 zip 83701)  
Idaho 83702 Tel. 208-343-2583

Saint Alphonsus Regional Medical Center, 1055 N. Curtis Rd., Boise  
Idaho 83706 Tel. 208-378-2121

St. Luke's Regional Medical Center, 190 E. Bannock St., Boise  
Idaho 83712 Tel. 208-386-2222

Verterans Affairs Medical Center, 500 W. Fort St., Boise  
Idaho 83702 Tel. 208-336-5100

Community Hospital, 551 Kaniksu St., Bonners Ferry (P.O. Box 1449)  
Idaho 83805 Tel. 208-267-3141

Cassia Memerial Hospital and Medical Center, 2303 Park Ave., Burley (P.O.Box 489)  
Idaho 83318 Tel. 208-678-4444

West Valley Medical Center, 1717 Arlington, Caldwell  
Idaho 83605 Tel. 208-459-4641

Valley County Hospital, 402 Old State Hwy., Cascade  
Idaho 83611 Tel. 208-382-4242

Pine Crest Hospital, 2301 N. Ironwood Pl., Coeur D' Alene  
Idaho 83814 Tel. 208-666-1441

Kootenai Medical Center, 2003 Lincoln Way, Coeur D' Alene  
Idaho 83814 Tel. 208-667-6441

St. Mary's Hospital, Lewiston & North Sts., Cottonwood (P.O.Box 137)  
Idaho 83522 Tel. 208-962-3251

Council Community Hospital, 205 N. Berkley St., Council  
Idaho 83612 Tel. 208-253-4242

Teton Valley Hospital, 283 N. First E., Driggs (P.O. Box 728)  
Idaho 83422 Tel. 208-354-2383

## Idaho

Walter Knox Memorial Hospital, 1202 E. Locust St., Emmett  
Idaho 83617 Tel. 208-365-3561

Gooding County Memorial Hospital, 1120 Montana St., Gooding  
Idaho 83330 Tel. 208-934-4433

Walker Center, 1120 A. Montana St., Gooding  
Idaho 83330 Tel. 208-934-8461

Syringa General Hospital, 607 W. Main St., Grangeville  
Idaho 83530 Tel. 208-983-1700

Eastern Idaho Regional Medical Center, 3100 Channing Way, Idaho Falls  
(P.O. Box 2077), Idaho 83404 Tel. 208-529-6111

St. Benedicts Family Medical Center, 709 N. Lincoln Ave., Jerome (P.O. Box 586)  
Idaho 83338 Tel. 208-324-4301

Shoshone Medical Center, Jacobs Gulch, Kellogg  
Idaho 83837 Tel. 208-784-1221

St. Joseph Regional Medical Center, 415 Sixth St., Lewiston  
Idaho 83501 Tel. 208-743-2511

Oneida County Hospital, 150 North 200 West, Malad City (P.O.Box 126)  
Idaho 83252 Tel. 208-766-2231

Mc Call Memorial Hospital, 1000 State St., Mc Call (P.O. Box 906)  
Idaho 83639 Tel. 208-634-2221

Bear Lake Memorial Hospital, 164 S. Fifth St., Montpelier  
Idaho 83254 Tel. 208-847-1630

Gritman Medical Center, 715 Washington St., Moscow  
Idaho 83843 Tel. 208-882-4511

Elmore Medical Center, 895 N. Sixth East St., Mountain Home (P.O.Box 1270)  
Idaho 83647 Tel. 208-587-8401

U.S. Air Force Hospital Mountain Home, 366 MG/SEL Attend to Lt. Jones 90  
Hope Drive, Mountain Home Air Force Base, Idaho 83648-100 Tel. 208-828-7600

Idaho State School and Hospital, 3100 11th Ave. N., Nampa  
Idaho 83687 Tel. 208-466-9255

Mercy Medical Center, 1512 12th Avenue Rd., Nampa  
Idaho 83686 Tel. 208-467-1171

Clearwater Valley Hospital, 301 Cedar, Orofino  
Idaho 83544 Tel. 208-476-4555

## Idaho

Bannock Regional Medical and Geriatric Center, 651 Memorial Dr., Pocatello  
Idaho 83201 Tel. 208-232-6150

Pocatello Regional Medical Center, 777 Hospital Way, Pocatello  
Idaho 83201 Tel. 208-234-0777

Franklin County Medical Center, 44 N. First East St., Preston  
Idaho 83263 Tel. 208-852-0137

Madison Memorial Hospital, 400 E. Main, Rexburg (P.O. Box 310)  
Idaho 83440 Tel. 208-356-3691

Minidoka Memorial Hospital and Extended Care Facility, 1224 Eighth St., Rupert  
Idaho 83350 Tel. 208-436-0481

Steele Memorial Hospital, Main and Daisy Sts., Salmon (P.O. Box 700)  
Idaho 83467 Tel. 208-756-4291

Bonner General Hospital, 520 N. Third Ave., Sandpoint (P.O. Box 1448)  
Idaho 83864 Tel. 208-263-1441

Caribou Memorial Hospital and Nursing Home, 300 S. Third West St., Soda Springs  
Idaho 83276 Tel. 208-547-3341

Benewah Community Hospital, 229 S. Seventh St., St. Maries  
Idaho 83861 Tel. 208-245-5551

Blain County Medical Center, 706 S. Main St., Hailey, Sun Valley (P.O. Box 927)  
Idaho 83333 Tel. 208-788-2222

Moritz Community Hospital, P.O. Box 86, Sun Valley  
Idaho 83353 Tel. 208-622-3323

Magic Valley Regional Medical Center, 650 Addison Ave. W., Twin Falls (P.O. Box 409)  
Idaho 83301 Tel. 208-737-2000

Twin Falls Clinic Hospital, 666 Shoshone St. E., Twin Falls (P.O. Box 1233)  
Idaho 83301 Tel. 208-733-3700

Memorial Hospital, 645 E. Fifth St., Weiser (P.O. Box 550)  
Idaho 83672 Tel. 208-549-0370

**Appendix B**  
**The Questionnaire**

**Medical Waste Treatment Techniques Used by Hospitals in Oregon, Washington, and Idaho**

I would like to ask you some questions about the medical waste stream and infectious waste stream in your hospital. Please refer to the following definition of medical waste when answering any questions.

*Medical or hospital waste is the waste that is generated in the diagnosis, treatment, or immunization of human beings or animals. It also includes regulated infectious waste from laboratory and testing procedures, and certain types of hazardous waste and household waste produced in the hospital.*

1. Does your hospital use the term "**regulated infectious waste**"? (Please circle one number, NA = not applicable in your hospital)

- 1 NO  
2 YES

1.1 Which Agency's definition is used in your facility? (Please circle one number for each category)

	NO	YES
a. Environmental Protection Agency Guideline.....	1	2
b. Centers for Disease Control Definition .....	1	2
c. Occupational Safety and Health Administration Guideline .....	1	2
d. Accreditation Agency Guideline (e.g. AHA, JCAHO)....	1	2
e. Professional Association Recommendation (e.g. AMA)...	1	2
f. State Regulation.....	1	2
g. Other: _____	1	2

1.2 Please indicate whether or not each category is most often considered to be regulated infectious waste in your hospital?

	NO	YES	NA
a. Microbiological Laboratory Waste.....	1	2	3
b. Pathological Waste (e.g. tissue).....	1	2	3
c. Blood Specimens and Blood Products.....	1	2	3
d. All Sharps.....	1	2	3
e. Only Contaminated Sharps.....	1	2	3
f. Body Parts (e.g. legs, arms).....	1	2	3
g. Waste from Surgery (e.g. dressing, sponges, drapes).....	1	2	3
h. Animal Blood and Blood Products, Liquid Forms, not Blood Contaminated Items.....	1	2	3
i. Dialysis Unit Waste (e.g. tubing, filters).....	1	2	3
j. Waste from Communicable Disease Unit.....	1	2	3
k. Chemotherapy waste.....	1	2	3
l. Contaminated Equipment.....	1	2	3

2. Does your hospital **segregate** regulated infectious waste from its medical waste? (Please circle on number)

- 1 NO  
2 YES



3. Does your hospital handle the disposal of sharps differently than other medical waste? (Please circle one number)

- 1 NO  
2 YES



3.1 Please indicate whether or not these following methods are used to handle the disposal of sharps in your hospital. (Please circle one number for each category)

	NO	YES
a. Autoclave.....	1	2
b. Incineration.....	1	2
c. Mail to other facilities.....	1	2
d. Send to a landfill.....	1	2
e. Other : _____	1	2

4. Please indicate whether or not containers for each of the following kinds of medical waste are labeled in a particular way.

	NO	YES	NA
a. Chemical Waste.....	1	2	3
b. Radiation Waste.....	1	2	3
c. Chemotherapy Waste.....	1	2	3
d. Regulated Infectious Waste.....	1	2	3
e. Other: _____	1	2	3

5. Does your hospital have special storage areas for medical waste ? (Please circle one number)

- 1 NO  
2 YES



5.1 Please indicate whether or not your hospital has special storage area for each of the following types of waste. For those where you do have a special storage area also indicate the area as IN (within the hospital building) or OUT (separated secure and against unauthorized trespass).(Please circle one number for each category)

	Have?			Where ?	
	NO	YES	NA	IN	OUT
a. Chemical Waste.....	1	2	3	1	2
b. Radiation Waste.....	1	2	3	1	2
c. Chemotherapy Waste.....	1	2	3	1	2
d. Regulated Infectious Waste.	1	2	3	1	2
e. Other: _____	1	2	3	1	2

6. Does your hospital have an Advisory Committee or Other Committee (s) responsible for medical waste treatment? (Please circle one number)

- 1 NO  
2 YES

6.1 Please indicate whether or not the committee is in charge of the following categories of medical waste. (Please circle one number for each)

	NO	YES	NA
a. Chemical Waste.....	1	2	3
b. Radioactive Waste.....	1	2	3
c. Chemotherapy Waste.....	1	2	3
d. Regulated Infectious Waste.....	1	2	3
e. Other: .....	1	2	3

7. Does your hospital regularly generate chemotherapy waste? (Please circle one number)

- 1 NO  
2 YES

7.1 Please indicate whether or not each of the following techniques are applied to dispose of chemotherapy waste in your hospital. (Please circle one number for each)

	NO	YES
a. Incineration.....	1	2
b. Landfilling.....	1	2
c. Being Processed as Hazardous Waste.....	1	2
d. Other: .....	1	2

8. Does your hospital currently have an incinerator to burn its waste? (Please circle one number)

- 1 NEVER HAVE HAD → Please answer question 10 (on page 4)  
2 YES, CURRENTLY USE → Please answer question 9 (on page 4)  
3 NO LONGER USE → Please answer question 8.1 and 8.2, and then skip to answer question 10 (on page 4)

8.1 When was the incinerator last operate?

- 1 DON'T KNOW  
2 IN THE PAST YEAR  
3 MORE THAN 1 YEAR BUT LESS THAN 5 YEARS AGO  
4 MORE THAN 5 YEARS BUT LESS THAN 10 YEARS AGO  
5 MORE THAN 10 YEARS AGO

8.2 Why did your hospital stop using its incinerator (s)? (Please circle one number for each)

	NO	YES
a. The incinerator could not meet federal or state waste disposal requirements	1	2
b. The incinerator could not meet air pollution control requirements.....	1	2
c. The maintenance of the incinerator was too expensive.....	1	2
d. Redesign of the incinerator was too costly.....	1	2
e. All of the above.....	1	2
f. Other: .....	1	2

9. How does your hospital dispose of incinerator ash? (Please circle one number)

- 1 IN-STATE SANITARY LANDFILL
- 2 OUT-OF-STATE SANITARY LANDFILL
- 3 DON'T KNOW
- 4 OTHER: \_\_\_\_\_

10. Other than incineration, please indicate whether or not each of the following methods are **used** to treat medical waste or hospital waste in your hospital, and for those methods used indicate if the treatment is conducted **ON-SITE**, **OFF-SITE** or **BOTH**. (Please circle one number for each)

	Used? (A)		Where? (B)		
	NO	YES	ON-SITE	OFF-SITE	BOTH
a. Autoclave.....	1	2	1	2	3
b. Chemical Disinfecting or Hydropulping....	1	2	1	2	3
c. Microwave.....	1	2	1	2	3
d. Irradiation.....	1	2	1	2	3
e. Grind and pour to Municipal Sewer System.	1	2	1	2	3
f. Pour to Municipal Sewer System.....	1	2	1	2	3
g. Macrowaving (Electrothermal Deactivation)	1	2	1	2	3
h. Deposit in a Landfill.....	1	2	1	2	3
i. Use of Private Medical Waste Hauler.....	1	2	1	2	3
j. Other: _____	1	2	1	2	3

11. In the last calendar year (1992), how much **medical waste or hospital waste** did your hospital produce each week on the average? (Please circle one number)

- 1 LESS THAN 50 POUNDS (e.g., 1-2 trash cans)
- 2 50 POUNDS - 99 POUNDS (e.g., 2-4 trash cans)
- 3 100 POUNDS - 199 POUNDS (e.g., 5-8 trash cans)
- 4 200 POUNDS - 299 POUNDS (e.g., 9-12 trash cans)
- 5 300 POUNDS - 400 POUNDS (e.g., 13-16 trash cans)
- 6 MORE THAN 400 POUNDS (e.g., more than 16 trash cans)

12. In the last calendar year (1992), how many pounds of **regulated infectious waste** is produced in each week, on the average?

- 1 LESS THAN 1 POUND
- 2 1-14 POUNDS (e.g., a plastic garbage bag)
- 3 15-29 POUNDS (e.g., one trash can)
- 4 30-119 POUNDS (e.g., 1-3 trash cans)
- 5 120-150 POUNDS (e.g., 4-6 trash cans)
- 6 MORE THAN 150 POUNDS (e.g., more than 6 trash cans)
- 7 DON'T KNOW

Thank you for completing this survey ; I appreciate your assistance.  
Please return the questionnaire in the stamped envelope provided.

NOTE: To receive a summary of the results, please print your name and address on the back of the return envelope.

**Appendix C**  
**The Cover-Letter and Follow-Up Cover-Letter**

***MEDICAL WASTE TREATMENT TECHNIQUES USED BY HOSPITALS IN  
OREGON, WASHINGTON, AND IDAHO***

September 1, 1993.

To : «Name», «Title»

Your hospital was randomly selected by the Oregon State University Department of Public Health to participate in a study investigating medical waste treatment techniques of hospitals in Oregon, Washington, and Idaho (EPA Region X). This study is the part of Master's thesis of graduate student in Environmental Health Management. The purpose of the study is to gather previously uncollected data regarding regional medical waste treatment and disposal practices. We hope that you will agree to participate in the study. Your response is very important to accurately profile current medical waste management practices in light of recent legislation passed at state and national levels.

Your participation is voluntary and results will be held in confidence. According to the pretest, this questionnaire can be easily finished in less than 10 minutes. The questionnaire is coded in such a way that your name or institution is not identifiable. The questionnaire is numbered only so that we will not bother you again once you have sent it in. You may receive a summary of results by writing your name and address on back side of the returned envelope (which will be separated from the questionnaire). Please complete the enclosed questionnaire promptly and return it in the stamped envelope provided as soon as possible.

I would be happy to answer any questions you might have. Please write or call at (503) 758-5632 any time.

Thank you for your assistance.

Sincerely,

Pornwipa Klangsins B.S. (Medical Technology)  
Graduate Student, Environmental Health Management  
Department of Public Health  
Oregon State University  
Corvallis, Or 97331-6406

Anna K. Harding R.S., Ph.D.  
Assistant Professor, Environmental Health  
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Oregon State University  
Corvallis, Or 97331-6406  
(503) 737-3832

***MEDICAL WASTE TREATMENT TECHNIQUES USED BY HOSPITALS IN  
OREGON, WASHINGTON, AND IDAHO***

October 1, 1993.

To : «Name», «Title»

Early in September, I mailed you a survey inquiring about medical waste treatment techniques used in your hospital. I have not yet received your completed questionnaire.

In order to acquire representative data regarding regional medical waste treatment and disposal practices, it is essential that each hospital in Oregon Washington and Idaho return the questionnaire.

This is the first comparative study of medical waste treatment techniques that has been conducted in this region. Also, the results are of particular interest to many participating hospitals as is evidenced by the number of requests for summary of materials.

As I mentioned in my last letter, this questionnaire is easily finished within 10 minutes. In the case that your questionnaire has been misplaced, a replacement is enclosed. I would like to urge you to complete and return it in the stamped envelope provided as soon as possible.

I would be happy to answer any questions you might have. Please write or call me, collect call (503) 737-7116 any time.

Your cooperation is greatly appreciated.

Sincerely,

Pornwipa Klangsins B.S. (Medical Technology)  
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